ILLUSTRATIONS OF USEFUL ARTS, MANUFACTURES, AND TRADES.

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(1858-1860)

INTRODUCTION.

On entering a well-appointed Museum of Natural History, the first impression made on the thoughtful observer is the *method* which pervades the whole. In becoming better acquainted with the animals, the plants, and the minerals which form the collection, he is made aware of the fact that their methodical arrangement is not for the sole purpose of facilitating study, but that such an arrangement actually exists in nature. An attentive examination of their structure, functions, and conditions of being, causes the various groups of natural objects to fall into their places in the chain of being, and leads to the solemn conviction that their relationship is the result of method, as their existence is of design.

If we were to do for the Useful Arts and Manufactures that which has been done with so much success for Natural History, we should have a museum of very grand proportions, the contents of which would most impressively illustrate a considerable portion of the history of civilisation. We should see collected therein various specimens of raw material from different parts of the world;—we should there be able to notice the influence of climate or of dissimilar modes of treatment in producing varieties of the same substance—the various changes which the raw material undergoes in passing from its crude state to that of a finished product—the various tools, machines, and engines concerned in the manufacture. We should also have models of workshops with the men at work—models, sections, and drawings of machines; pictorial representations of processes; and in connexion with this vast display would be a library of reference for the use of the student in *Technology*, as we are now accustomed to term the whole business of the Useful Arts.

That such a museum does not exist in a nation so eminently manufacturing as Great Britain, may well excite surprise. Measures, however, are being taken to supply, to some extent at least, the deficiency. Professors of Technology have been appointed in London, Edinburgh, and Dublin, and collections are being formed in those capitals for the purpose of illustrating their lectures.

Supposing such a museum to be in existence, and that we were required to produce a catalogue illustrative of its nature and extent, its scope and object, the result would be in some respects such a work as the reader has now before him. The writer has had considerable intercourse with the manufactories of this country, and by far the larger proportion of the following engravings were made under his direction.

The Useful Arts originated in the necessities of man's nature which required food, clothing, shelter, warmth, artificial light, and thousands of comforts and conveniences, many of which, commencing perhaps with luxuries confined to the few, came in the course of time to be necessaries claimed by the many. As men lived in societies, subdivision of labour would naturally arise; one set of men would confine their attention to the production or preparation of one article only; in course of time they would not only become very skilful in their *handicraft*, a word which itself implies *skill of hand*, but they would also, by constant trials and repeated failures, hit upon the best means and materials for bringing about a certain result. Thus would originate an *art*, or *trade*, or *mystery*, terms which imply—the first, *skill*, the second, *use* or *experience* (i.e. *trodden*, or frequently gone over), and the third, *secrets*, known only to the initiated, and only to be revealed to the apprentice in the course of his seven years' teaching.

In this way originated the more important or indispensable of the Useful Arts, thousands of years before Science had any real existence. They originated, we have said, in the necessities of man's nature, and so far resemble language, hearing, seeing, walking, or any other necessary operation; but it would be difficult to say what share of them belongs to man's intellect, and what to the teaching of a higher power. But for this last influence, there would be many processes in the Useful Arts which could not possibly be accounted for in the absence of Science, and some which even Science cannot yet explain. We are, however, relieved from the necessity of speculating on this point, by the direct information of Holy Scripture. We read (Exod. xxxi. 3) that God himself filled

Bezaleel, the son of Uri, with His Spirit "in wisdom and in understanding, and in knowledge, and in all manner of workmanship, to devise cunning works; to work in gold, and in silver, and in brass, and in cutting of stones," &c. (See also ch. xxxvi. 1. 1 Kings vii. 14. Isaiah xxviii. 26—29.)

During the long period that Science either did not exist, or existing did not advance, the Useful Arts attained a considerable degree of perfection, and then remained stationary because their object seemed to be attained. Science ceased to advance because she mistook her object; she was lagging behind, investigating the causes of things instead of the laws of phenomena; and it was not until Lord Bacon directed her into this her true path, that Science made progress; but her progress once begun, was rapid. The career of discovery, which she is still pursuing with ardour, was graced by numerous gifts to the Useful Arts, which, stimulated by her progress, and encouraged by her example, underwent a great and momentous change—the work of an individual was multiplied a thousand-fold by a machine—the shop became a factory—the power of the hand was replaced by the arm of the steam-engine—power, in fact, became developed with scarcely any limit, and production became all but illimitable. To represent fairly such progress as this, our *Industrial Museum* would indeed require to be of vast proportions, and our *Illustrations* to extend to great length. All we hope and purpose to do, is to afford some glimpses of the great result, and arranging the materials placed at our disposal in methodical order, to give the reader correct information so far as it extends, and a desire to know more on a subject, to which, under Providence, our beloved country owes so much of her greatness and prosperity.

King's College, London,
1858.

I.—COTTON.

THE first object that meets the eye on entering our Industrial Museum is the Cotton Plant; and we shall have no difficulty in explaining how it thus comes to occupy the first rank among our manufactures, when we learn that the cotton consumed in Great Britain in the year 1856 amounted to 920,000,000 lbs., the cost of which was £23,958,000 sterling; that the value of the goods produced amounted to £61,484,000; considerably more than half of which, or goods to the value of £38,275,770, were exported, and of this sum £8,056,671 was received for yarn alone. The total quantity of cotton imported into the United Kingdom in 1856 amounted in round numbers to 1,023,000,000 lbs., of which 113,000,000 lbs. was re-exported chiefly to the north of Europe. In 1857 the import amounted to 970,000,000 lbs.; in 1858 to 1,034,000,000 lbs.; and in 1859 to 1,226,000,000 lbs. or 10,946,331 cwt. Of this last named quantity the United States of America supplied 8,586,672 cwt., Brazil 200,705 cwt., Egypt 336,313 cwt., British East Indies 1,717,240 cwt., and other countries 105,401 cwt. The prices of cotton have varied considerably in different years from 5*d.* to 10*d.* per lb.; but for picked sea-island cotton, as much as 2*s.* 6*d.* per lb. has been paid. With such a demand on the cotton-growing districts of America (amounting as it did in 1859 to about four-fifths of our whole supply), it is no wonder that the British Government, the manufacturer, and all who think at all on the subject, should contemplate with some uneasiness the prospect of a deficient supply of the raw material. The failure of a single harvest in the United States would indeed be to us a national calamity. Thousands of persons would thereby be thrown out of employment,—not only persons engaged in factories, but sailors and engineers, carpenters and builders, carriers and retail dealers in cotton goods, and many others whose trades and occupations are subsidiary to this vast manufacture;—so mutually dependent are we upon each other's exertions, and all, more or less so, on a due supply of the raw material.

It is curious that such vast machinery, and such vast and complicated results, depend upon the downy covering of an oily seed, which might at first sight appear to have been intended to protect the germ of the future plant, and afterwards to be rejected. We appropriate the covering and reject the seed. A cotton plantation is a nursery for cultivating plants simply for the sake of this downy substance; no other part of the plant being of any commercial value, although cotton-seed oil promises to become so. The country most celebrated for these extensive nurseries of the cotton plant is the southern portion of the United States of America. There are, doubtless, other portions of the world equally well adapted to the growth of cotton, such as British India, parts of Australia, the West Indies, &c. with the advantage of being in our own colonies, and, therefore, more under control than an independent country. But commerce, in spite of British enterprise, is very much a matter of habit, and loves to run in the groove which custom and precedent have marked out for it; so long therefore as America continued to supply the raw material in sufficient quantity, we thought not of deficient harvests, nor of being supplanted by rival consumers, nor of the chances of slave labour in the United States being mitigated, or suppressed, when the conviction shall be forced upon slave owners, as assuredly some day or other it must, that slavery is inconsistent with the Christianity which both black men and white profess. We were satisfied too with the answer to the question, why British India or Australia did not grow cotton, when told, that the one wanted roads, and that the other was an undeveloped country; that in one the natives did not clean and prepare the cotton as we require it, and that in the other there was no labour to be spared.

Within the last few years, however, the prospect of a deficient supply and the consequent rise in price, have so alarmed our manufacturers, that earnest attempts are being made to raise cotton in some of our colonies, so that we may no longer be dependent on America for the great bulk of our supply.

The cotton plant (*Gossypium herbaceum*), fig. 1, grows in India, China, Arabia, Persia, Asia Minor, and some parts of Africa, and is the variety cultivated with so much success in America. It is a member of the order *Malvaceæ*, which contains our common mallow, to which it bears some resemblance: the seed-vessel, however, is different,—the surface of the seed-coat in the cotton plant presenting a thick growth of vegetable hairs or filaments, the length of which, or *length of staple*, as it is called, greatly determines the value of the cotton.

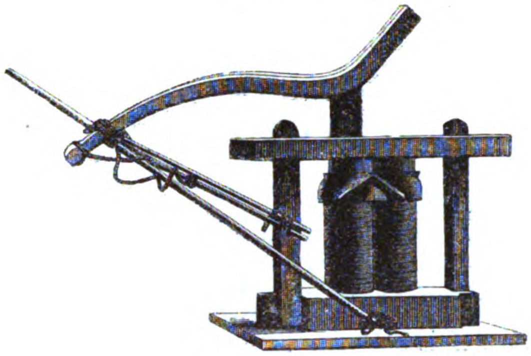
The discovery of cotton wool and cotton fabrics in ancient Peruvian tombs, proves that the cotton plant is indigenous in America. The *G. Barbadense* is the species which has supplied the cotton of North America, and of the West India islands: that of Brazil, Peru, and South America generally, is the produce of the *G. Peruvianum*, a species marked by its black seeds, and their adhering firmly together. From North America, the *G. Barbadense* was introduced into the Mauritius and the Isle of Bourbon, and thence to India, where the plant has become a permanent variety, and its produce is called *Bourbon cotton*. The great bulk of the native-grown cotton is produced from the indigenous species, with little variation either of culture or of manufacture during three thousand years.

The Indian cotton-plant, known to botanists as a distinct species, under the names of *G. Indicum* and *G. herbaceum*, has a wide range in India, growing in the hottest and moistest as well as the driest districts. The varieties arising from soil and climate are all shorter in staple than the American cottons, and in this consists their chief inferiority for the European market. But the Indian cotton has advantages of its own: its colour is good; it takes dye well; and yarns spun with it swell in bleaching, whereby fabrics woven with it acquire a close texture. The famous muslins of Dacca show how fine the manufactures are of which it is capable. In all the varieties the cotton wool fills the seed-pod, and at length causes it to burst, thereby presenting a ball of snowy-white or yellowish down, consisting of three locks, one for each cell, enclosing and firmly adhering to the seeds, which resemble grapes in size and shape. In addition to the herbaceous, there is the *shrub* and the *tree cotton*. A specimen of the latter is shown in fig. 6. But the herbaceous, which is an annual, is the more valuable. The character of its foliage and flower in different stages of maturity may be further judged of by the border to fig. 5. The cotton plant requires a light sandy soil, and, contrary to the character of most other plants, prospers in the vicinity of the sea. The American sea-island cotton thrives on certain low sandy islands which extend from Charlestown to Savanna, and is remarkable for its long fibre, and strong and silky texture. The cultivators of Georgia grow three varieties of herbaceous cotton; the first, named *Nankin* cotton, from its yellow colour; the second, *green-seed* cotton; and the third, *sea-island* cotton. The first two grow in the midland and upland districts; and a fine white variety is known as *upland cotton*, or, from a method of cleaning it, *bowed Georgia cotton*. When the cotton is ripe, it should be gathered with the seeds, to the exclusion of the outer husk; for if the whole pod be taken, the husk breaks into small pieces which cannot be readily separated.

The first preparation which the cotton undergoes is the separation of the seeds, which, if done by hand, is a slow and tedious operation. Hence, the locks are, in some parts of India and China, passed through a couple of rollers which, being turned by hand, the seeds fly off as the locks pass through. Two of these primitive cotton gins are represented in figs. 2 and 4. The cotton

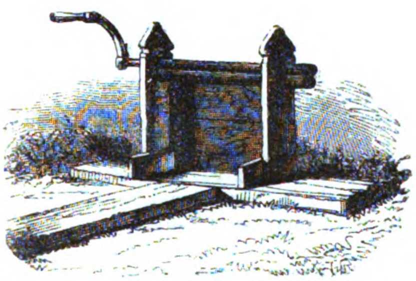
COTTON.

1. HERBACEOUS COTTON (*Gossypium herbaceum*).



2. HINDOO COTTON GIN.

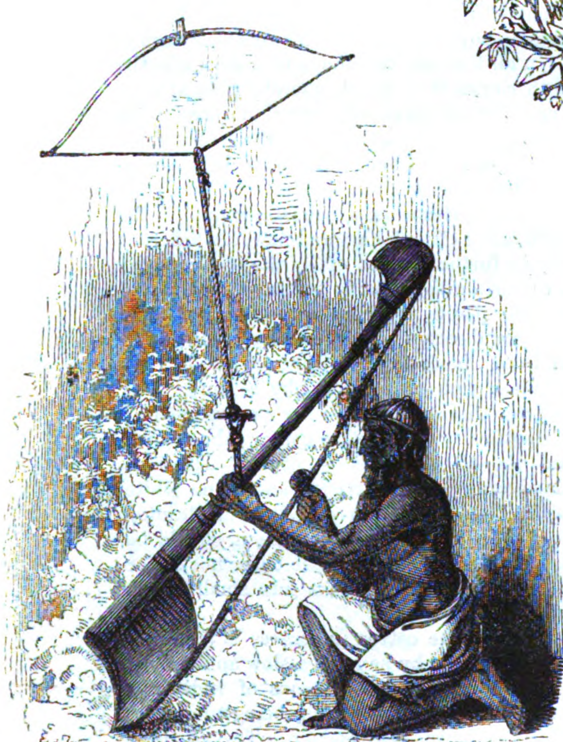
3. HINDOO SPINNING WHEEL.



4. PRIMITIVE COTTON GIN.

5. THE SPINNING-WHEEL.

6. TREE COTTON (*Gossypium arboreum*).



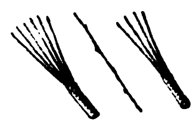
7. "BOWING" COTTON.

8. HALL-IN-THE-WOOD, NEAR BOLTON.

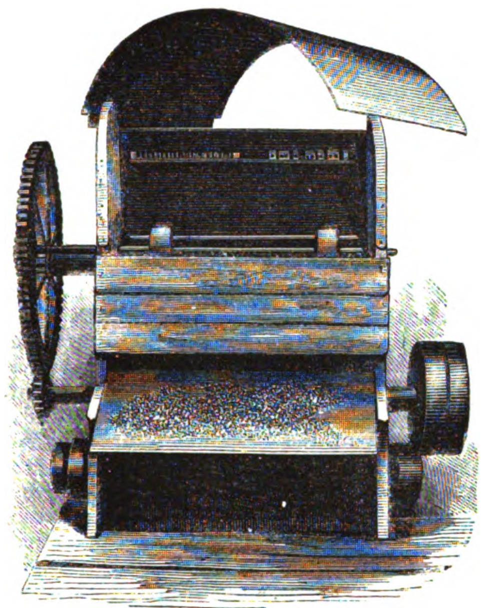
9 SPINNING WITH DISTAFF AND SPINDLE.

10. BATTING.

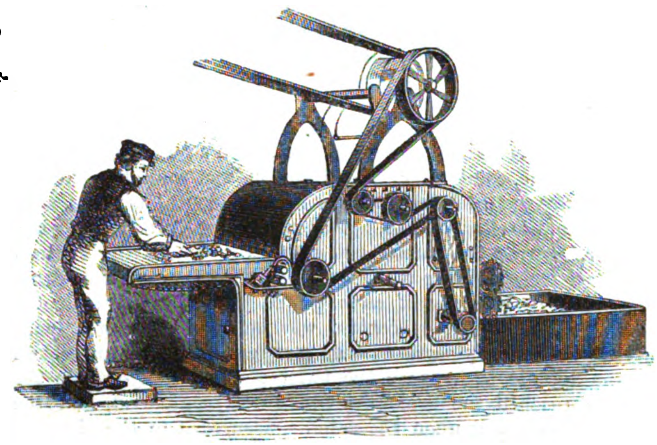
12. FORMING LAPS BY HAND.



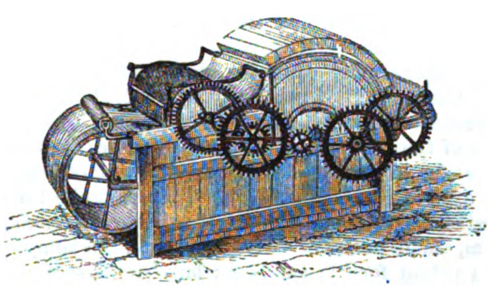
11. FANS USED IN BATTING AND LAPPING.



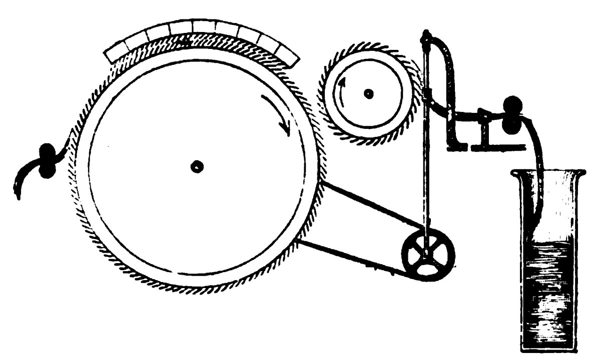
13 OPENING OR COTTON CLEANING MACHINE.



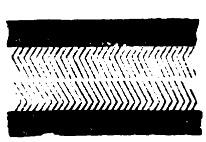
14. OPENING MACHINE.



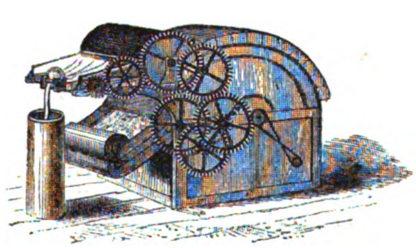
15. FIRST CARDING ENGINE.



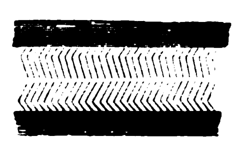
16. WORKING PARTS OF CARDING ENGINE.



18. PORTIONS OF CARDS FOR CARDING.



17 SECOND CARDING ENGINE.



19. PORTIONS OF CARDS FOR DOFFING.

is next cleaned by *bowing*, so called from a large *bow*, suspended in the manner shown in fig. 7, the string of which is made to vibrate in the midst of a heap of cotton, thereby causing the filaments to open and disperse in a loose flocculent state, during which particles of dirt escape and fall to the floor. A man can clean by hand only one pound of cotton per day; but by means of one of these rude machines, the produce of his labour is increased forty and from that to sixty-five fold. The gin in use in the United States will clean as much as 340 lbs. in a day. This is *Whitney's saw-gin*, in which the cotton is put into a hopper, one side of which is formed by a series of parallel wires, one-eighth of an inch apart. Close to the hopper is a roller, set with circular saws, an inch and a half apart; and as they revolve they pass between the wires of the hopper, and their teeth seize on the locks of cotton and drag them through the wires, leaving the seeds behind, which are too large to pass. The cotton is removed from the saws by means of a revolving cylindrical brush.

The two great objects for which a cotton-mill is erected and furnished with much costly and complicated machinery, are, first, to place the fibres side by side in parallel lengths, and secondly, to twist them into yarn. These objects were, until towards the latter end of the last century, performed by hand, or with the assistance of the spinning-wheel; and so generally were young females engaged on this employment of spinning the fibres of wool, flax, or cotton into yarn, that the name of *spinster* was applied to them, which they still retain. The most ancient implements were the distaff and the spindle, the one consisting of a stick or reed about three feet long, with a fork near the top, on which the combed or carded cotton was wound, while the spindle was a reed, less than a foot in length, serving as a winder to the thread, the upper part being furnished with a slit for securing the thread, and the lower end having a whorl or wheel for steadying it. Fig. 9 represents an ancient dame at work with the distaff and spindle. She is drawing out a thread from the carded cotton, working and twisting it with her fingers, and imparting every now and then a turn or two to the spindle to increase the twist of the yarn. When the spindle reached the ground, a *length* was completed, and the spinster wound it upon the spindle, secured it to the slit, and proceeded with another length.

The natives of Hindostan had for ages a much quicker method than this of spinning cotton yarn. In fig. 3 an attempt is made to represent the Hindoo spinning-wheel; but as the artist who draws machinery does not always understand what he is copying, and has a keener eye for pictorial effect than accuracy of detail, so in the case before us we have a very pleasing picture, but a very inaccurate machine. The large wheel should be furnished with an endless band which should reach as far as the small upright block of wood, and passing over a small wheel therein, set it rapidly in motion, whenever the large wheel is slowly turned by the hand of the spinner. To this small wheel is attached the spindle containing a *cop* or small bundle of cotton, from which the spinner draws out a yarn while it is in the very act of being twisted. The *Jersey wheel* or *Saxon wheel* was introduced into England about the reign of Henry VIII. It is correctly represented in fig. 5, which also shows the mode of working it: its pleasant hum long continued to be a familiar sound in every cottage, and indeed in every house, for fine ladies did not scorn to occupy their leisure with the appropriate work of spinning. The cotton was prepared for the wheel by being first *carded*, combed or brushed with wire-brushes called *hand-cards*, consisting of wire teeth fastened to cards of leather; two of these are represented on the floor in fig. 5. The fibres being thus made to lie in one direction, the whole of the cotton was divided into a number of soft fleecy rolls or *cardings*, each about a foot in length, and one of these being attached to the spindle, the spinster turned the wheel with one hand and drew out the carding with the other; when drawn out to a sufficient length, it was wound upon the spindle, and another carding being attached was in like manner twisted and drawn out until a continuous *roving* was produced. This was called *coarse* spinning; and in order to produce a tolerably fine thread, it was necessary to spin and draw out the rovings by repeating the process of spinning. In these operations the quality of the thread depended greatly on the skill and delicacy of touch of the spinster. When a firmer and more equal yarn was required, flax was employed; but it was difficult for the spinners to produce the required supply of yarn for the weavers, so that cotton, calicoes, and linens fetched high prices so long as they were dependent upon the spinning-wheel. About the middle of the last century, a poor but very clever man, named Hargreaves, tried to make the spinning-wheel more productive. He had often attempted to spin with several spindles at once, holding the several threads between the fingers of the left hand, but the horizontal position of the spindles interfered with his success. While he was meditating on his favourite subject, one of his children happened one day to upset a spinning-wheel while it was at work, and Hargreaves saw to his surprise that the spindle continued to revolve, and give out yarn in a vertical, instead of the usual horizontal position. We do not know why this circumstance should have excited surprise, only we are aware that things which are very obvious when pointed out to us, are obscure enough if left to our own sagacity to discover. The spindle of the spinning-wheel had hitherto all the world over revolved in a horizontal position, and now it was seen for the first time to revolve vertically. Hargreaves took the hint; the thought occurred to him that if a number of spindles were placed upright and side by side, a number of threads could be spun at one time. Accordingly he succeeded about the year 1767 in contriving a frame with eight spindles in a row, and eight rovings being attached to them, the loose ends were placed within a fluted wooden clasp, which when shut held them tightly: this clasp was drawn by the left hand along the frame to a distance from the spindles, while the spinner with his right hand turned a wheel, which by an endless band set a drum in motion, and the latter in its turn also, by means of endless bands, set all the spindles spinning. Eight lengths being thus spun, the clasp was returned to its original position; the spindles being at the same time made to revolve gently, the finished yarn was wound upon them; the clasp being again opened, fresh lengths of rovings were attached and spun out as before. The number of spindles set in motion in one frame was afterwards increased from 8 to 80. Such is the origin of the famous *spinning-jenny*, a representation of which will be found among the spinning apparatus (fig. 31); but we may mention that the word *jenny or jinny*, is from *gin* or *engine*, the new machine being called a *ginny*, and the process *ginning*. The writer of these pages was informed by a grandson of Hargreaves, that the term originated in a remark made by the wife of the inventor to her daughter Mary, who was spinning with the new frame: "Thou *gins* away famously." It is commonly but erroneously stated, that the word *jenny* was named after Jane, one of the inventor's daughters. Hargreaves kept his discovery secret for some time, but the quantity of cotton spun by his family excited suspicion, and the spinners broke into his house and destroyed his machine. On this Hargreaves removed to Nottingham, where he erected a small mill on the jenny plan. He took out a patent for his machine; but having sold several machines before he thought of applying for legal protection, his patent was of no use to him, and the spinning-jenny became the property of the nation.

The next great invention in the art of spinning cotton by machinery, sprang from the crude idea of drawing out the cotton by passing it between several pairs of rollers, moving at different and increasing rates of speed. Several names are mentioned in connexion with this invention, and it is certain that so early as 1738, Lewis Paul of London took out a patent for a machine "for the spinning of wool and cotton in a manner entirely new." In the specification of this patent the process described is identical with that which is commonly attributed to Arkwright; the sliver "is put betwixt a pair of rowlers" which

draw in the cotton intended to be spun in proportion to their velocity, and "a succession of other rowlers moving proportionately faster than the rest, draws the sliver into any degree of fineness that may be required;" in addition to which "the bobbyn, spole, or quill upon which the thread is wound is so contrived as to draw faster than the first rowlers give, and in such proportion as the sliver is proposed to be diminished." These words contain the fundamental idea of spinning by machinery. Paul's machine does not appear to have been known in Lancashire, and was not very successful in Yorkshire. At any rate, thirty years elapsed before Thomas Highs, a reed-maker of Leigh, and John Kay, a clock-maker, contrived a machine for spinning by rollers, which was not very successful until Richard Arkwright, originally a poor barber of Bolton, became acquainted with the new machine, and seeing its capabilities, devoted himself to its improvement, and after encountering many difficulties, was enabled in 1769 to take out his first patent for spinning cotton with rollers. Add to this the invention of a young weaver, named Samuel Crumpton, who combined the spinning-jenny of Hargreaves with the roller spinning of Arkwright in a machine called the *Mule* or the *mule-jenny*, and we have the three great inventions of this manufacture. In the last-named machine, the spindles, instead of being stationary, were placed on a moveable carriage which was wheeled out to the distance of about five feet in order to stretch and twist the yarn, and was wheeled in again, in order to wind it on the spindles. Crumpton was a weaver by trade, and occupied a picturesque old mansion in a retired and beautiful spot near Bolton. This house, named *Hall-in-the-wood*, is represented in fig. 8. Crumpton's object in his invention was to supply his own loom with good yarn, but he could not keep his invention to himself: persons climbed up to his windows to watch him at work, and the mule not being protected by patent soon came into general use. The first machine was constructed for some 20 or 30 spindles, but mules are now made to carry from 2,000 to 3,000 spindles.

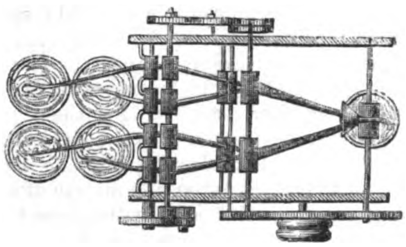
The southern part of Lancashire, with Manchester for its capital, is the chief locality of the cotton trade; the site having been determined by the abundance of what may be called the sinews of manufactures, viz., water power, fuel and iron; for with these, machinery may be manufactured and set in motion at the smallest cost, and many of the finishing processes for textile fabrics, depending as they do on the agency of water and heat, may be conducted with advantage.

Let us now trace the progress of a bale of cotton through a cotton-mill, until it is sent out again in the form of a bundle of yarn. Liverpool is the great mart for raw cotton, and hither the cotton spinners resort for the purpose of purchasing it. A bale of cotton from the United States weighs on an average 430 lbs.; Egyptian cotton 384 lbs.; East Indian 276 lbs.: West Indian 201 lbs.; and Brazilian 181 lbs. The bags or bales are sent by rail to Manchester, and the first operation in the mill is to unpack and to sort. In order to insure a cotton of one quality, the bags as they are opened are spread in layers one above the other, forming what is called a *bing* or *bunker;* and when the cotton is taken for the various operations of the mill, it is raked away from the vertical side of this cotton stack, by which means a certain quantity of each bag is made to mix up and blend with the other bags, the result being an equal quality from specimens which differ somewhat in quality. The locks of cotton being tangled in the gathering, and matted together by pressure in the bale, and moreover being somewhat dirty, are now opened and cleaned. If the cottons are of fine quality intended for fine spinning, they are *beaten* or *batted* by hand, as shown in fig 10, with twigs of hazel or holly, three or four feet long. In this operation the cotton is placed upon a frame, the upper surface of which is made of cords, so as to form a kind of elastic grating; and as the cotton is violently beaten, the tangled locks become opened, the dust and loose impurities fall to the ground between the cords, but the fragments of seed-pods which adhere firmly are picked out by hand. The cotton thus cleaned is spread in a weighed quantity, upon a length of canvas contained in a frame as shown in fig. 12, and is made to lie pretty evenly thereon, by means of fans of wood shown in fig 11, after which the whole is rolled up into a *lap* for supplying another machine. For the ordinary purposes of common spinning, the cotton is opened and cleaned in a machine called a *willow* or cotton cleaning machine, fig. 13, The cotton is placed upon an endless apron, the motion of which feeds a couple of rollers which are furnished with coarse teeth: these seize the cotton, draw the locks apart, and pass them on to other rollers with finer teeth, by which the fibres are further opened, while the impurities are thrown out at the bottom. Some of the rollers revolve at the rate of about 500 turns per minute. In another machine, fig. 14, the cotton is held and delivered slowly by a pair of rollers, during which it is subjected to the blows of beaters arranged like the spokes of a wheel and revolving with great rapidity, by which means the particles of sand, dirt, &c., are shaken out, while the flakes of cotton are wound upon a roller in such a way as to form a continued sheet of a loose fleecy texture, also called a *lap;* the same, in fact, as was done by hand in fig. 12.

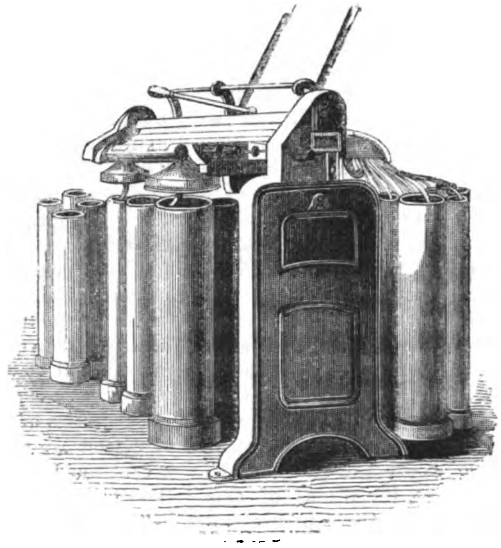
The laps thus formed are made to feed the first *carding-engine*, where the fibres are further separated and disentangled, freed from the remaining impurities, and disposed in tolerably parallel order. A cotton card is a sort of wire-brush, consisting of bent pieces of hard drawn iron wire, called *dents* or *teeth*, fixed into a band or fillet of leather, or what is better, of a compound of cotton, linen, and india rubber. When leather is used, the holes are apt to enlarge by the motion of the teeth, so that these become loose; but the elasticity of the india rubber and its adhesion to the wire allow of considerable play without any enlargement of the holes. These fillets or cards are made to cover the surface of drums of various sizes, and the cotton is combed out upon these drums, and transferred from one to another in a manner which we will now briefly explain.

Fig. 18 represents a portion of two combs, with the teeth placed in opposite directions: if a tangled lock of cotton wool be placed on the lower card, and this be moved towards the left, while the top card is moved towards the right, and the operation be repeated a number of times, it is obvious that the lock will be disentangled and combed out, and the fibres laid side by side in parallel order, or nearly so. The lock will, however, be buried among the teeth of the comb; and in order to disengage it, all that is necessary is to reverse one of the cards, as in fig. 19, and moving one upon the other, the lock will be removed from the lower card to the upper. We shall now be able to understand the action of the carding-engine, the working parts of which are represented in fig. 16. On the left hand side the lap is seen approaching the large drum of the carding-engine between a couple of rollers. The drum, moving upon its centre in the direction of the arrow, takes up the fibres of the lap and distributes them over its surface, and they are combed out by means of a number of straight pieces placed over the drum and furnished with teeth bent in an opposite direction to those of the drum. As the fibres come round, they are taken up by a smaller drum, moving in an opposite direction to the large drum, from which they are removed in the form of a delicate fleece by means of a *doffing comb*, to which a rapid chopping motion is imparted by attaching the rod which bears it to a crank, or to a point a little out of the centre of the wheel which gives motion to the comb. As the web is removed from the small drum, it is drawn through a cone-shaped piece of metal: it is then passed between a couple of rollers, which condense it somewhat, and it is lastly received into a can, in which it coils itself up in a spiral form. It is now called a *card-end* or *sliver*. In fine spinning, the cotton is passed through two carding-engines, the first being called a *breaker-card* (fig. 15), and the second a *finishing-card* (fig. 17), in which the teeth are set finer than in the former.

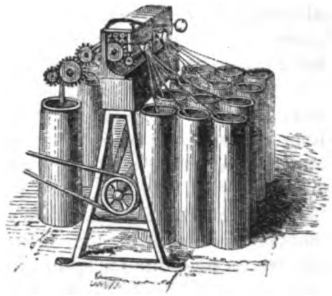
The spongy slivers from the carding-engine are next passed between rollers revolving at different rates of speed, for the pur-



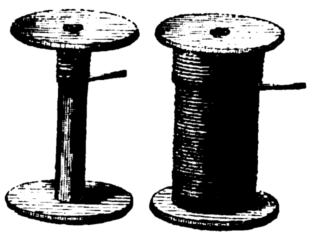
20. DRAWING 4 INTO 1).



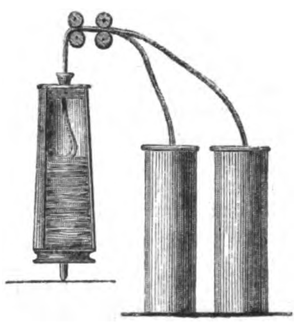
21. DRAWING FRAME.



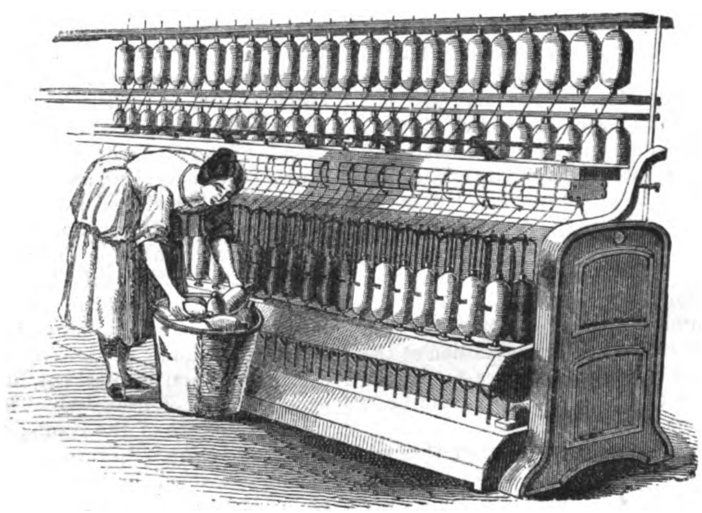
22 DRAWING (12 INTO 1).



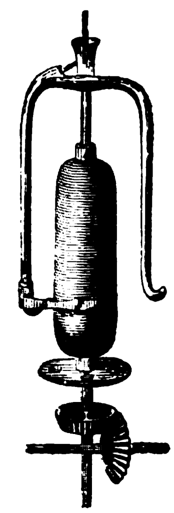
23. BOBBINS.



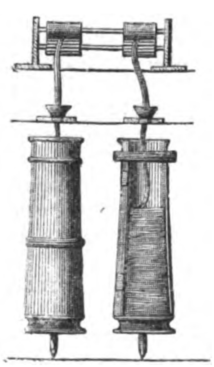
24. ROVING.



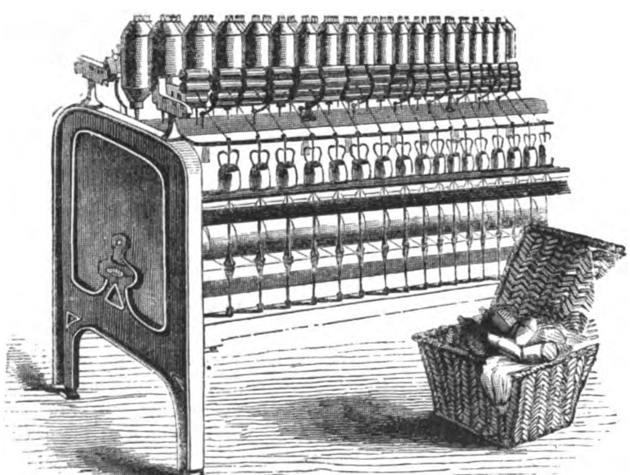
26. ROVING FRAME.



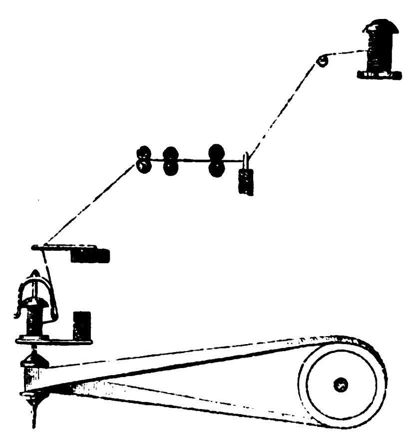
27. BOBBIN, FLY AND SPINDLE.



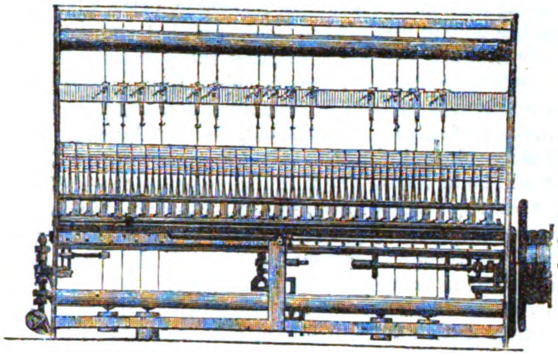
25. ROVING.



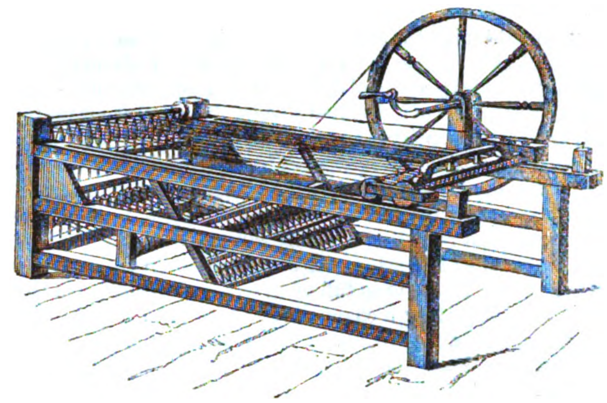
28. COMMON THROSTLE.



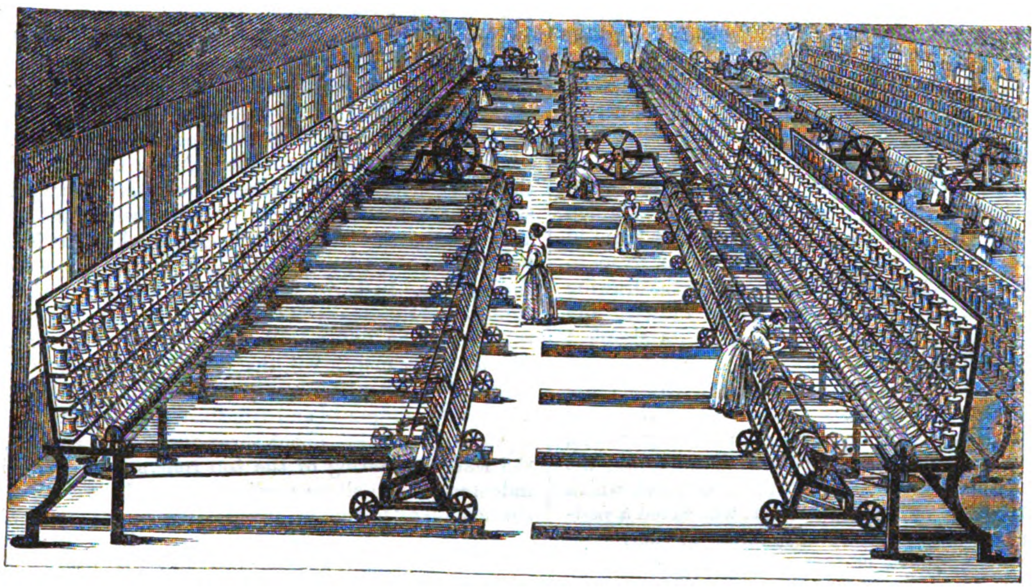
29 WORKING PARTS OF THE THROSTLE.



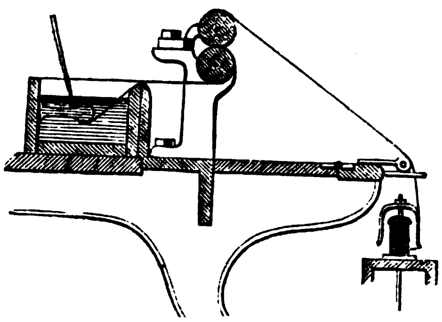
30. IMPROVED THROSTLE.



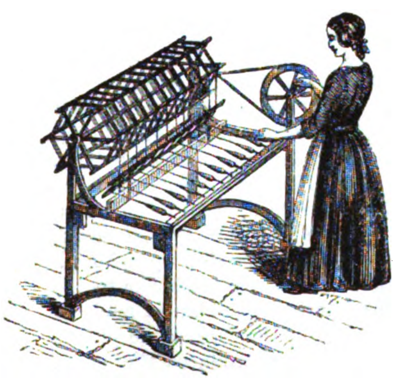
31. HARGREAVES'S SPINNING JENNY.



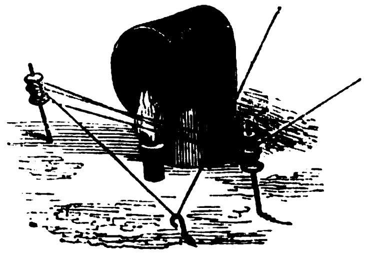
32. MULE SPINNING.



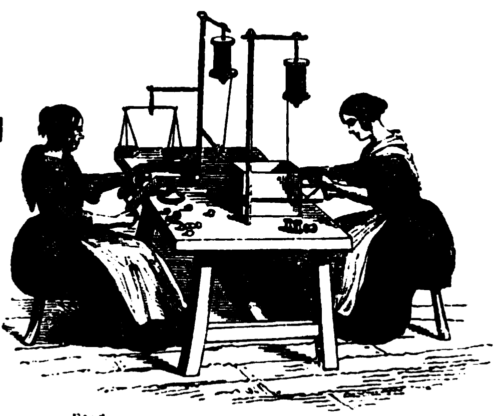
35. SECTION OF THREAD FRAME.



33. REELING.



34 GASSING THE YARN.



36. BALLING AND REELING.

pose of straightening the filaments, unfolding such as are doubled, laying them side by side in parallel order, and by placing a number of slivers side by side and drawing them out into one, serving to correct the defects of individual slivers. The *drawing-frame* (figs. 20, 21, 22) usually consists of three pairs of iron rollers, the upper one of each pair being covered with leather, while the lower are fluted in the direction of their length: the upper ones are also weighted so as to produce considerable pressure. The under rollers are driven by wheel-work at various rates of speed, and they cause the upper ones to revolve by friction. At the back of the machine are placed the cans full of slivers, and a number of these are guided usually along a channelled surface to the rollers, where they are united, and the sliver, thus doubled many times, is drawn out, in passing through the rollers, into a uniform sliver of greatly increased length, which is also coiled up in a can placed for its reception. The drawing is usually repeated a number of times: for example,—for coarse spinning, six card-ends are usually passed through the first drawing-head and formed into one riband; six of these ribands are again drawn and doubled into one; six of these are formed into a third sliver, and five of these are passed through the last drawing-head; so that the doubling of the fibres of the carding has been multiplied $6 \times 6 \times 6 \times 5 = 1080$ times. For fine spinning the drawings are carried to a much greater extent.

The cotton as it leaves the drawing-frame is in the form of a loose, porous cord, the fibres of which are parallel. It is too thick to be spun into yarn, and too tender to be further reduced in size by drawing alone; if, however, a slight twist be given to it, the fibres will be made a little more compact, and the drawing may be proceeded with. This double process of drawing and twisting is called *roving*. The *roving-machine*, in its simplest form (figs. 24, 25), consisted of two pairs of drawing-rollers for extending the slivers, of which two were generally doubled and united, and the sliver as it quitted the drawing-rollers was received into a can which was made to spin rapidly round, thereby giving a slight twist to the sliver, and thus forming the roving. The roving had next to be wound upon bobbins, which was done first by hand, and afterwards by what was called a *jack-frame;* this led to the *bobbin-and-fly frame*, which is the *roving-machine* now in use. The object of this machine is to give the slivers a slight twist, and then to wind them on the bobbins. The twist is accomplished by the revolutions of a *spindle;* the winding is a more complex operation. The spindle of which we are now speaking is a round steel rod, a portion of which is shown in fig. 27; and it is made to revolve rapidly by means of the small cog-wheels, one of which is attached to the spindle itself, and the other, which is in gear with it, is attached to a horizontal rod, which derives its motion by being in gear with one of the main moving shafts of the mill, which latter, of course, derive their motion from the steam-engine of the establishment. The bobbin may be of the shape represented in fig. 23, or it may consist simply of a piece of hollow tube: it is threaded upon the spindle, and the small bed or platform on which it rests is made to revolve by another series of wheels, not shown in the figure. The spindle has two arms, called the *fly* or *flyer:* it fits by a square or six-sided hole to the top of the spindle, and can be removed in an instant when it is required to put on or take off the bobbin. One arm of the fly is hollow, and the other solid; and the roving-frame (fig. 26) may contain 100, 200, or more spindles, in a double row. This arrangement being understood, the action of the machine is as follows:—The sliver, having been drawn by the rollers, is twisted by the rapid revolution of the spindle into a soft cord, or roving; this enters a hole in the top of the spindle and passes down the hollow arm of the fly; it is then twisted round a steel finger, as shown in fig. 27, which winds it on the bobbin with a certain pressure. In order to wind the roving evenly on the bobbin, the delivering finger is made to move up and down, or rather the bobbin is made to slide up and down on the spindle, an effect which is produced by causing the bed upon which the bobbins rest to have a slow rising and falling motion. It is further necessary, as the winding proceeds and the bobbin increases in thickness, that the spindle should slightly diminish its speed, otherwise the roving might be improperly stretched or broken: this is effected by causing the strap which connects the motions of the moving shafts to act on a conical, instead of a cylindrical drum, so that by properly moving the strap along its surface a varying rate of speed is insured. It will be understood that the spindle and the bobbin are driven at different rates of speed, for if they both moved at the same rate, the roving would be twisted merely, and not wound upon the bobbin; but by making the bobbin revolve a little quicker than the spindle, the winding is accomplished. For example, if the bobbin revolve fifty times and the spindle forty, forty turns of the bobbin will have nothing to do with the winding; but there are ten turns of the bobbin above those of the fly which will perform the winding. Hence, forty turns of the spindle produce twist, while fifty turns of the bobbin wind ten coils of the roving upon its barrel.

There are two sets of bobbin-and-fly frames, viz. the *coarse* and the *fine*, or the *first* and the *second* roving-frames: they are the same in principle, only the first has fewer spindles, and is fed with slivers from cans filled at the drawing-frame and placed at the back of the machine. The second roving-frame is fed with rovings, or, as they are sometimes called, *slubbings*, from bobbins filled at the first roving-frame: these bobbins are arranged on upright skewers, fixed in a shelf or creel placed behind the roller-beam, as shown in fig. 26. The roving from these bobbins is made to pass through wire eyes, to prevent it from being torn obliquely from the bobbins. In fig. 26, the most important part of the apparatus, namely the *roller-beams*, is not made out, but the position of the rollers will be understood by referring to figs. 24, 25, and 29. It should be mentioned, that before the sliver enters the back pair of drawing-rollers, the guides through which it is led having a slow side motion to and fro, shift the sliver alternately to the right and to the left about three-quarters of an inch, to prevent the leather covering of the top rollers from becoming worn or indented by the sliver passing constantly over the same line of surface. The bobbin-and-fly frame is superintended by a female, whose duty it is to join the broken slivers, to remove the full bobbins, and to place empty ones in their stead.

The rovings are usually finished either at the *throstle* or at the *mule-jenny*. In the throstle (figs. 28, 29), the roving from each bobbin passes through three pairs of drawing-rollers, by which it is extended to the requisite degree of fineness. On coming out of the last pair of rollers, each roving is guided towards the spindles by means of a small ring, or a notch of glass let into the frame; the spindles revolve with great rapidity, so that the flyers make a low musical hum, which is said to have given the name of *throstle* to this machine. The roving, or *yarn*, as it may now be called, passes through an eyelet at the end of one of the arms of the fly, and proceeds to the bobbin, on which it is wound by the following contrivance:—The bobbin fits loosely on the spindle, and one end rests upon a shelf. As soon as the fly is set spinning, the yarn drags the bobbin after it, and makes it follow the motion of the spindle and fly; but the weight of the bobbin, and its friction on the shelf, cause it to hang back somewhat, the effect of which is to keep the yarn stretched, and to wind it on the bobbin much more slowly than the fly revolves. The yarn is equally distributed on the bobbin by giving it a slow up and down motion. Thus it will be seen that the throstle is similar to the bobbin-and-fly frame, only in the latter the bobbin is made to revolve by a distinct movement, while in the former the pull of the yarn, which is now sufficiently strong, produces the effect. The throstle spins a strong, wiry thread, well adapted for *warps*, as those threads are called which represent the length of a piece of woven cloth. The throstle does not spin very fine yarn, because this would not bear the drag of the bobbin; fine yarn therefore is usually spun at the mule.

The spinning-mule (several of which are shown in fig 32, which represents a portion of one of the floors of a cotton-mill

at Manchester) consists of two principal portions: the first, which is fixed, contains the bobbins of rovings, and the drawing-rollers; the second is a sort of carriage moving upon an iron railroad, and capable of being drawn out to a distance of about five feet from the fixed frame. This carriage carries the spindles, the number of which is half that of the bobbins of rovings. Motion is given to the spindles by means of vertical drums, round which are passed slender cords, communicating with the spindles. There is one drum to every twenty-four spindles.

The carriage being run up to the point from which it starts in spinning, the spindles are near to the roller beam; the rollers now begin to turn and to give out yarn, which is immediately twisted by the revolution of the spindles; the carriage is then moved away from the roller beam, somewhat quicker than the threads are delivered, so that they receive a certain amount of stretching, a circumstance which gives value to this machine. The beneficial effect is produced in this way; when the thread leaves the rollers, it is thicker in some parts than in others, and those thicker parts, not being so much twisted as the thinner ones, are softer, and yield to the stretching power of the mule so that the twist is equalised throughout, and the yarn becomes more uniform. When the carriage has completed a *stretch*, or is drawn out from about 54 to 64 inches from the roller beam, the drawing-rollers cease to give out yarn, but the spindles continue to whirl until the threads are properly twisted. In spinning the finer yarns, the carriage sometimes makes what is called a *second stretch*, during which the spindles are made to revolve much more rapidly than before. The drawing, stretching, and twisting of a length of thread being thus completed, the mule disengages itself from the parts of the machinery by which it has hitherto been driven, and the spinner then seizes the carriage with his left hand, and pushes it back to the roller beam, turning at the same time with his right hand a fly wheel, which gives motion to the spindles. At the same time a *copping wire*, as it is called, is pressed upon the threads by the spinner's left hand, and they are thus made to traverse the whole length of the spindle, upon which they are then wound or *built* in a conical form which is called a *cop*. These cops are used for placing in the shuttle in weaving, and form the *weft*, or short cross threads of the cloth.

One man is able to attend to two mules, guiding in the carriage of one mule by hand, while the carriage of the other is being moved out by the steam engine. Much skill is required in pushing back the carriage. As a preparatory step, the spinner causes the spindles to revolve backwards for a moment, to slacken the threads just completed, and throw them off the points of the spindles previous to winding them. In pushing the carriage back he must attend to three things; he must guide the copping wire so as to insure the regular winding of the yarn on the cop; he must regulate the motion of the spindles; and he must push the carriage at such a rate as to supply the exact amount of yarn that the spindles can take up in a given time.

The spinner is assisted by boys or girls called *pieceners*, to *piece* or mend the broken threads. He also employs a *scavenger* to collect all the loose or waste cotton, called *fly*, which lies on the floor, or hangs about the machinery. This is afterwards used chiefly in cleaning the machinery. It is calculated that the waste from the different machines in spinning cotton amounts to $1\frac{1}{2}$ oz. per lb. or nearly $\frac{1}{10}$th of the original weight. It is the duty of the piecener to join the broken ends of the threads as the carriage moves from the upright frame. The breaking of the thread depends, in some degree, on the temperature and the state of the atmosphere. During an east wind the threads sometimes break faster than the pieceners can join them, and it seems probable that the rapid whirling of so many thousand pieces of machinery produces in very dry weather a large amount of electricity, which may prevent the proper spinning of the fibres. At such times it is not uncommon to keep the atmosphere of the room moist by jets of steam, and to maintain a temperature of from 68° to 76°. Indeed, fine yarn cannot well be spun at a lower temperature.

The self-acting mule does the work of the spinning mule without the assistance or attendance of any one except the piecener. It is one of the most extraordinary machines in the cotton manufacture.

It will be understood from the foregoing description, that throstle-yarn is wound upon bobbins, while mule-yarn is formed into cops. If this yarn is intended to form the warp, or length of a woven piece, it is wound off into measured lengths of 840 yards each. These are called *hanks*. The reel for winding and counting hanks (fig. 33) is six-sided. It is a yard and a half in circumference, and is mounted in a carriage which carries the spindles or skewers that bear the bobbins or cops. The carriage has a slow traverse motion, parallel to the axis of the wheel, for spreading the thread upon its surface. When the wheel has completed 80 turns, a check is struck, showing that a *ley* or *rap* of 120 yards has been formed: seven of these raps make a hank of 840 yards. The woman who minds the machine ties the hanks round with a string, slips them off the wheel, and proceeds to wind another set. The size of the yarn is ascertained by weighing the hanks, and applying the following rule:—Divide 1000 grains by the number of grains in a ley, and the quotient will give the number of hanks to a pound. This rule is based on the fact that a ley is one-seventh of a hank, and 1000 grains equal to one-seventh of a pound. The average number of hanks to the pound is, for coarse spinning, from ten to forty: for candle-wicks, coarse counterpanes, &c. such low numbers as two hanks to the pound are manufactured. What is called No. 240 yarn is largely exported for the use of the finest foreign muslin manufacturers. In such yarn 240 hanks, each containing 840 yards, or a length of 114 miles, are produced from one pound of cotton. In the Great Exhibition of 1851, yarns of the degree of fineness represented by No. 700 were exhibited. Such a yarn is equal to 334 miles per pound. When the cotton is worked up into the finer kinds of lace, the original shilling's worth of cotton wool, before it passes into the hands of the consumer, may have been increased to the value of 300*l*. or 400*l*.

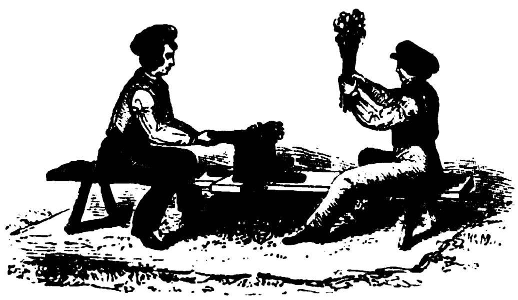
Fine yarns are disfigured by a number of minute, loosely projecting fibres, which must be removed before they can have that level, compact appearance which is required in the manufacture of bobbin-net lace thread, and for hosiery. This is done by passing the yarn rapidly through a gas flame, as shown in fig. 34, whereby the loose filaments are completely burnt off, and the yarn is improved in appearance and value.

When two or more yarns are twisted together, they form what is properly called *thread*. There are various kinds of thread, such as *lace-thread*, *stocking-thread*, *sewing-thread*, *&c*. The machine for doubling and twisting yarns into thread (fig. 35) resembles the throstle, already described (fig. 29). The yarns are unwound from bobbins or cops, and are then led through a very weak solution of starch, which enables them to be twisted into a more solid thread, and on emerging from the trough, the yarns, to the number of two, three, four, or six, according to the required size of the thread, are guided between a couple of rollers, which lay them parallel; they are then passed down to the eyelet of the flier, the rapid revolutions of which twist them into a solid cord or thread, which is wound upon the bobbin. The twist usually given to the doubled yarns is in an opposite direction to the twist of the individual yarns. The thread is made up into hanks for dyeing or bleaching, after which it is wound upon bobbins, for the purpose of being made up into balls or wound upon reels (see fig. 36).

38. METHOD OF SUPPORTING FLAX.

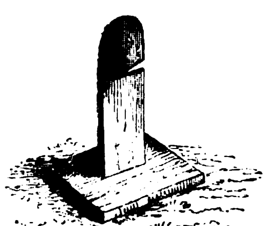
37. THE FLAX PLANT.

39. SHEAVES OF FLAX.

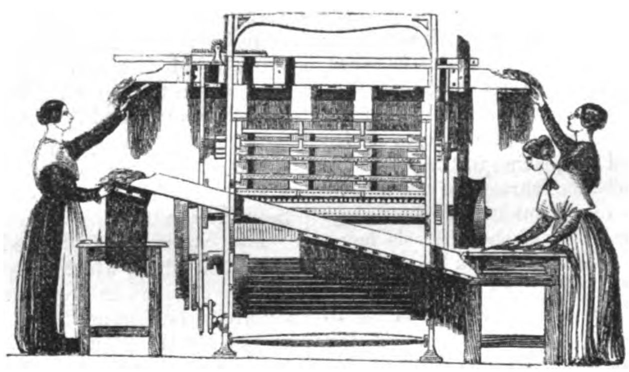


40. RIPPLING

41. THE BRAKE.

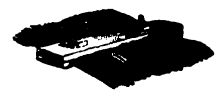


42. SCUTCHING FRAME.

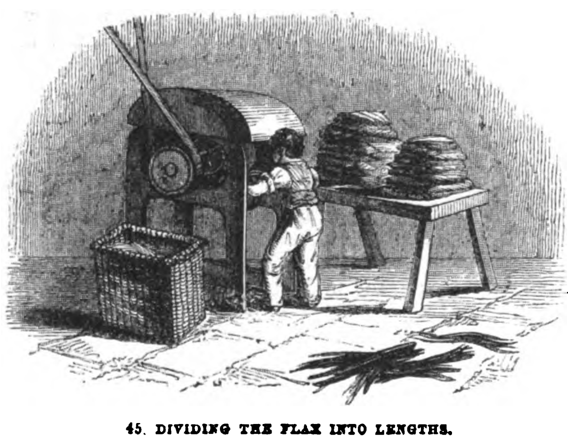


44. BRUSHING MACHINE.

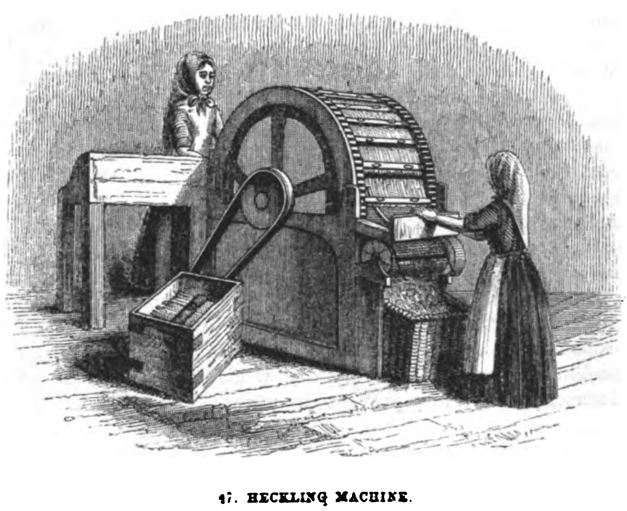
43. THE SCUTCHER.



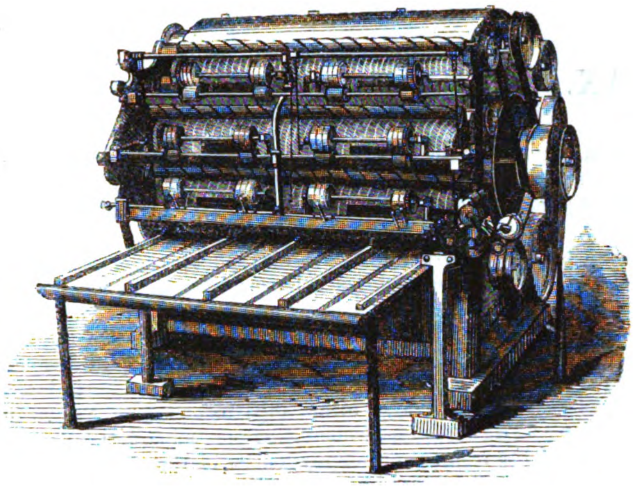
46. HOLDER.



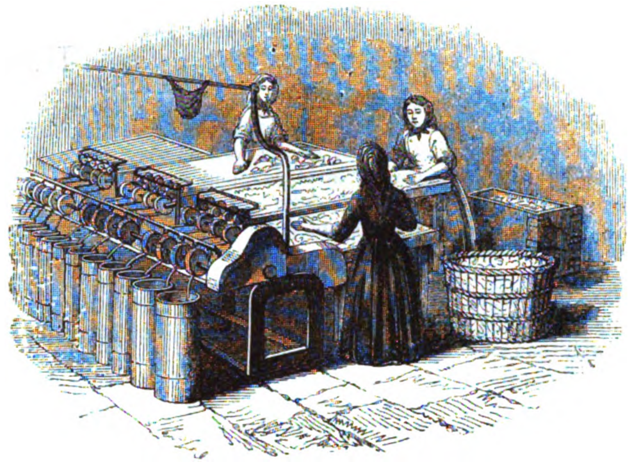
45. DIVIDING THE FLAX INTO LENGTHS.



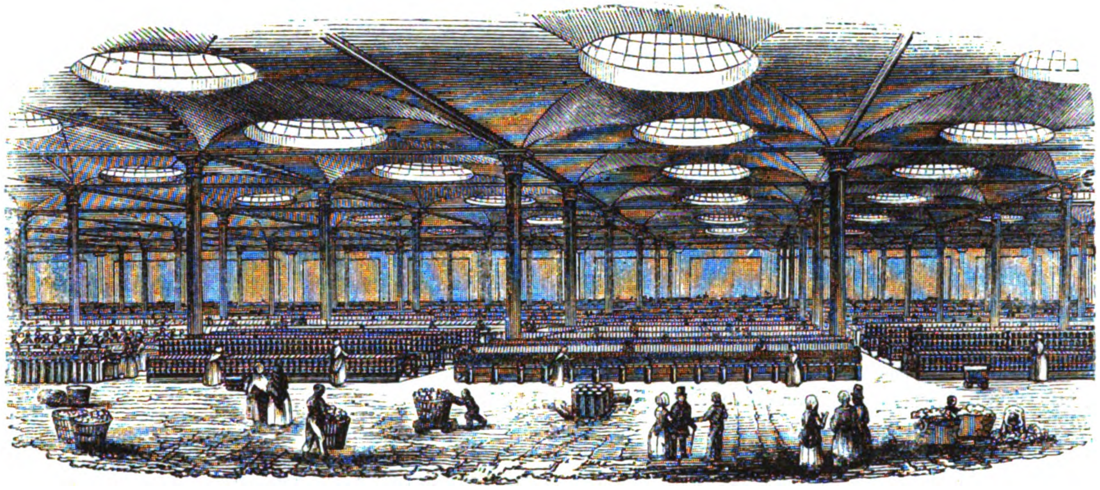
47. HECKLING MACHINE.



48. TOW CARDING ENGINE



49. SPREADING-FRAME.



. INTERIOR OF MARSHALL'S ONE-STORIED FLAX-MILL AT LEEDS.

51. THE ROOF OF MARSHALL'S ONE-STORIED FLAX-MILL.

5 THE FLAX SPINNING-WHEEL

II.—FLAX.

Of the four great materials of clothing, and other textile fabrics, viz. cotton, linen, silk, and wool, linen is one of the most ancient. The art of preparing the fibres of flax, and weaving them into linen cloth, had reached a high degree of perfection among the Egyptians so early as the time of Joseph, for we read (Gen. xli. 42) that Pharaoh arrayed Joseph in vestures of fine linen, while specimens of the very same fine linen are occasionally brought before our notice on partially unrolling some of the mummies which have been removed from their original place of sepulture to swell the crowd of curiosities in our museums.

The flax plant (*Linum usitatissimum*, fig. 37) is an annual. It sends up slender fibrous stalks two or three feet high, with narrow alternate leaves and delicate blue flowers; these are succeeded by globular seed-vessels, the cells of which enclose bright, slippery, brown, flattened and elongated seeds called *linseed*, which furnish the well-known oil. The stalks are hollow tubes, the filaments of which supply the material for cambric, linen, and similar fabrics. Flax has a wide range of growth, especially in temperate regions; it flourishes in the British Islands, and accommodates itself to a variety of soils, a mixture of sand and clay being the best. It forms an important part of the agriculture of Ireland, reclaimed bog-land furnishing good crops. It occupies the ground only a short time, namely, from April to July, so that another crop can be taken from the soil during the same season. The seed for sowing is usually of foreign growth, that of Riga being preferred; but the soil and climate of Egypt appear to be particularly suitable to this crop, and a large amount of our imports of late years have been from that country. The seed is first sorted into seed for sowing, and seed for crushing out the oil. The quantity sown per acre varies, but it is found that thin sowing promotes a coarse growth of the plants, while thick sowing produces tall and slender stems of fine fibre. When the young plants have risen to the height of two or three inches, they are carefully weeded by women or children, who creep along upon their hands and knees, with their faces to the wind. This is found not to crush the plants so much as if they went on their feet, and, on a breezy day, the wind will raise the plants to their former position. In June, the delicate blue blossoms open, and flax is then one of the most beautiful of crops. In some cases, to prevent the crop from being laid by the wind, stakes are driven into the ground at regular intervals, and small ropes tied to them, as shown in fig. 38. When the seed bolls appear, and before the seed is quite ripe, the flax must be pulled: if left until the seed is ready to drop, the plant dies, its juices become exhausted, and the fibre loses its silky and elastic character. The pulling is carefully done by small handfuls at a time, and these are laid across each other to dry; after which they are collected into bundles, and arranged as in fig. 39, with the root ends on the ground.

In order to separate the woody portion of the stem from the fibre, the plant is steeped in water; but, if the seed be sufficiently ripe to be separated, the upper ends are passed between the teeth of a comb, or *ripple* as it is called, consisting of smooth round iron teeth standing about twelve inches out of a block of wood, and fastened down to a long stool, where two men, seated one on each side, alternately draw a handful of flax between the teeth, as shown in fig. 40. Then comes the steeping, or *retting* as it is called, for which purpose the flax is placed in ponds of soft water, or in a slow-flowing river, with stones to sink it beneath the surface, and a covering of straw to shade off the light. In the course of from eight to twelve days, during which the plant undergoes fermentation, the woody portion is sufficiently retted or *rotted* to separate easily from the fibre. The flax is therefore taken out of the water, and placed on the banks to drain, after which it is spread out on the land to dry. Retting produces a very unpleasant and unwholesome odour in the neighbourhood, and imparts a noxious quality to the water. Instead of *water-retting*, or steeping the flax in a pond, *dew-retting* is in some places adopted, where the flax is exposed to the influence of dews and rain; this requires a longer time than the former operation, hence *mixed retting* is sometimes preferred where the flax is macerated in water, and the retting is finished in the air. A still better method of retting is by means of steam, for which purpose the flax is steeped in large circular vats, and the temperature is raised by a steam pipe to about 90° Fahr. In the course of a few hours fermentation sets in, and the decomposition of the resinous or gummy matter of the stalk proceeds rapidly. After about sixty hours the decomposition is complete, and the flax may be taken out and dried either in the open air or by artificial means. In some cases, the *vat-retting* is assisted by an alkaline solution. The cultivation of flax, including the retting, is such a delicate operation, that, according to its greater or less success, the price of the fibre may vary from 40*l.* to 80*l.* per ton.

When the flax is dry it is bruised, in order to separate the woody parts. Various implements are employed for the purpose, among which is the *brake* (fig. 41). This consists of two wooden frames, attached to each other by a hinge, furnished with bars, those of the upper frame fitting into the spaces of the bars in the lower frame. The upper set of bars may be brought down upon the lower set by means of a treadle, on releasing the pressure from which a spring attached to the upper frame separates the two. It is by a repeated action of this kind that the woody portions of the flax are bruised and separated from the fibre, an object which is now also accomplished by means of rollers.

The next operation is *scutching*, which still further cleans the fibre. The *scutching frame* (fig. 42) is a board, set upright in a block of wood, with a slit cut out of the side. The bruised flax is held in the left hand and inserted in the slit so as to project from it; here it is repeatedly struck with a flat sword or *scutcher* (fig. 43), the blows being directed close to the slit, through which the flax is gradually drawn, by which means the woody portion or *boon*, as it is called, is got rid of. The cleaning of flax is sometimes accomplished by machinery, fluted cylinders being employed for breaking, while arms or beaters projecting from a horizontal axle, and moving rapidly round, are used for scutching, and revolving brushes complete the cleaning. This mode of treatment greatly improves the appearance of the flax. The *brushing machine* (fig. 44) is sometimes used at this stage.

When the flax arrives at the mill in order to be spun into linen yarn, the first operation is to divide it into lengths, the necessity for which will be understood when it is considered that flax varies in length from 26 to 36 inches, and that the part nearest the root is coarse and strong, the middle part fine and strong, and the upper part finer but not so strong. In some cases flax is divided into four parts, which are named respectively *middles*, *ends*, and *middle* and *end-middles*. The flax must not be divided by cutting but by tearing, so that the rough or ragged ends may twist together into an equal thickness. The *dividing machine* (fig. 45) consists of upright wheels for holding the flax, and a centre wheel furnished with oval teeth for dividing it; the centre wheel moves with great speed, while the outer or holding-wheels move slowly, so that the dividing wheel has time to perform its work before the handful of flax which the boy puts in has time to escape from the pressure of the holding-wheels.

The filaments of flax thus divided are next cleaned, split into finer fibrils, and arranged in parallel order by a process called *heckling*. At the same time the short fibres, which form *tow*,

which are unfit for spinning, together with dust and dirt, are removed. The *heckle* is a comb of iron or steel teeth, sharply pointed, let into a brass or iron plate, and attached to a block of wood. Heckles are of various degrees of fineness, according to the degree of fineness required in the *line*, as the flax fibre is now called. In using the heckle, the workman takes a *strick*, or lock of flax, by the middle, throws it upon the points, and draws it towards him. By repeating this operation many times, with different heckles, the tow is separated and the line prepared for spinning.

Heckling is often performed by machinery, for which purpose a quantity of flax is spread out, and fixed in an iron vice or holder (fig. 46). A number of these vices being filled, they are hooked to a revolving drum (fig. 47), so as to allow one set of projecting ends in each holder to fall upon an internal drum, which is covered with sharp heckling teeth, and made to revolve with considerable speed in a direction contrary to that of the external drum. When the holders have travelled a certain way upon the outer drum, they are thrown off upon a rail, whence they are removed to a second heckling machine, which heckles the other side of the strick. They may even be made to pass through a third machine, where the teeth, being set finer on the drum, do their work more perfectly. The holders are next opened, and the stricks re-arranged, so as to allow those parts of the fibres to be acted on which had previously escaped the points. The brushing machine (fig. 44) is arranged somewhat on the plan of the heckling machine; but its inventor does not divide the flax into so many lengths as is usual, nor does he make so free a use of the heckling points.

The line now consists of long, fine, soft, glistening fibres, of a bright silver-grey or yellowish colour. As the tow collects among the heckle points, it is removed from them by means of brushes attached to wooden cylinders. The tow, being similar to cotton in its fibre, is somewhat similarly treated: it is transferred from the brushes to a revolving drum covered with cards, as in fig. 15, from which it is removed by a crank and comb, as in fig. 16: it is then carded a second time, and is reproduced as a continuous sliver (fig. 17). This is transferred to the drawing-frames (figs. 20, 21, 22), and is extended by means of rollers in the usual way, the parallelism of the fibres being assisted by heckling points. The slivers are next formed into rovings, wound upon bobbins, and spun into a fine but not very strong thread.

An improved form of *Tow Carding Engine* is shown in fig. 48. In this engine, the tow is passed round the carding cylinders, and is removed by three separate doffers, arranged at different distances, so as to take off three distinct qualities of tow. These are formed into slivers, and are led off at the side of the machine, where they are deposited in cans for the drawing-frame.

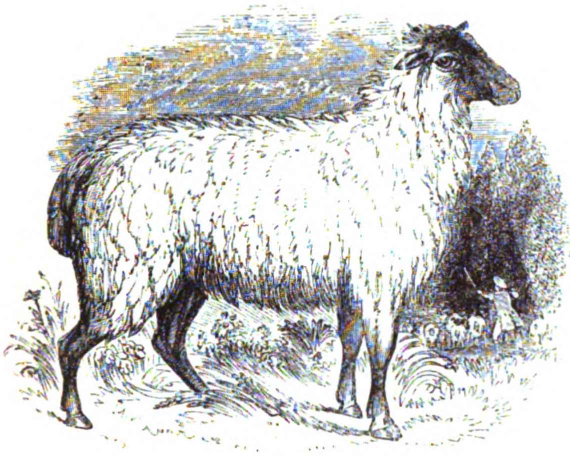
A few years ago, a proposal was made to convert flax into a cotton-like substance, by steeping it in a solution of carbonate of soda, and then adding a dilute solution of sulphuric acid. The hollow cylinders of the fibres being thus charged with the alkaline carbonate and afterwards with the acid solution, carbonic acid gas is instantly generated within them, and the expansive force of the escaping gas splits up the fibres into a vast number of riband-like filaments, which considerably resemble raw cotton. This *flax cotton*, as it is called, admits of being treated in the same manner as cotton.

We now return to the heckled flax or line. The operations preparatory to spinning are *spreading*, *drawing*, and *roving*. The line is first placed upon the feeding-cloth of a *spreading-frame* (fig. 49) in such a way that the ends of one strick may reach to the middle of the next. The flax is then passed between a pair of rollers, which deliver it through heckling points to another pair of rollers, and these, moving much more quickly than the first pair, increase the length and diminish the thickness of the line, and form it into a flat, narrow riband or sliver, which is deposited in a tin can. The slivers are transferred to a drawing-frame, where a number of them are drawn out repeatedly, as in the case of cotton, and they receive a slight degree of twist at the roving-frame, where they are wound upon bobbins, preparatory to spinning.

The flax spinning-wheel (fig. 52) has been, for the most part, superseded by those vast collections of machinery, which present so impressive a spectacle in the interior of a flax-mill. Still, however, the delicate manipulations of the hand have not been altogether superseded by the coarser but more productive results of the machine. Among the prizes awarded by the Jury (Class XIV.) of the Great Exhibition of 1851, was the sum of ten pounds to Ann Harvey, of Belfast, for perfection in quality of hand-spun flax yarn; a similar prize to a little girl ten years of age, belonging to the Heepen Spinning School, Bielefeld, Germany; and a similar prize to Jane Magill, of Belfast, 84 years of age, for the finest hand-spun yarn. We must, however, turn from the spectacle of youth and age competing together with equal success, and conclude this notice with a few words on machine-spun flax yarn.

The spinning of flax resembles the throstle-spinning of cotton, with the additional fact that the flax fibres require to be wetted in order to make them adhere to each other, and to render them more pliable and easy to twist. The spinster at the domestic wheel is accustomed to moisten the fibres with her lips; in the factory, water of the temperature of about 120° is contained in a trough which runs the whole length of the spinning-frame; the rapid motion of the spindle causes a dewy spray to be constantly thrown off, and gives to the air of the room a hot, steamy effect. The yarn is made into linen thread by doubling, which thread, after having been bleached, is formed into balls or wound upon reels. The yarn itself is also wound upon reels, and then made up into *leas*, *hanks*, *bundles*, and *bunches*. Thus 300 yards of thread form one lea, 3,000 yards one hank, 60,000 yards one bundle, and three bundles make one bunch. The size or fineness of linen yarn is reckoned by the number of leas to the pound weight. From 300 to 400 leas is reckoned fine spinning; but the old woman of 84 years of age already noticed produced 760 leas. Ann Harvey's was about 600 leas.

Fig. 50 represents the interior of one of Messrs. Marshall's flax-mills in the neighbourhood of Leeds. It consists of one magnificent room on the ground floor, 396 feet long by 216 feet wide, presenting an area of nearly two acres. In this noble room, the machinery is arranged in parallel lines along the length, with spaces between and among them for the attendants. The room is lighted from the roof, which is formed of brick-groined arches, 66 in number, supported by iron pillars, with a conical skylight in the centre of each arch. Under the floor of this room are the shafts for imparting motion to the machinery, together with gas and water pipes, carpenters' shops and warehouses, hot and cold baths for the use of the operatives, &c. On ascending to the roof of this 2-acre room, the visitor is surprised to find himself in a grass field (fig. 51) with sheep feeding, and the conical skylights rising like so many glass tents or greenhouses. The use of the grass on this extensive roof is to prevent the sun from acting injuriously on the roof covering, which consists of a mixture of coal-tar and lime: over this is a layer of earth, eight inches thick, which supports the grass. The mode of draining this roof is by making the iron pillars, which support it, hollow pipes, so that the rain water readily passes down them to be disposed of below. The upper extremity of each pipe is covered with a grating, to prevent the channel from being stopped up.



53. THE SOUTHDOWN SHEEP

51

55. THE ARGALIS.

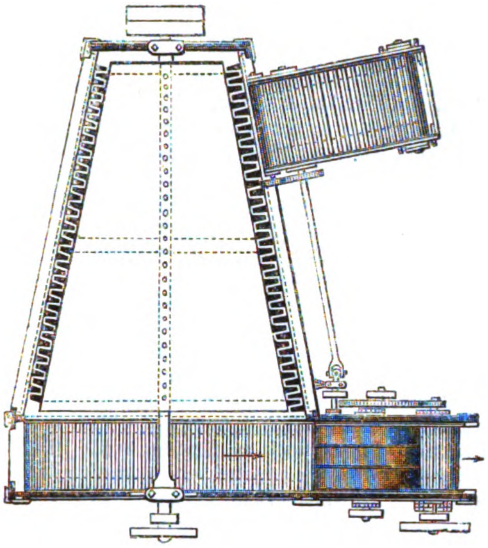
56. SHEEP WASHING.

58. SHEEP SHEARING.

57. HIGHLAND FLOCK.

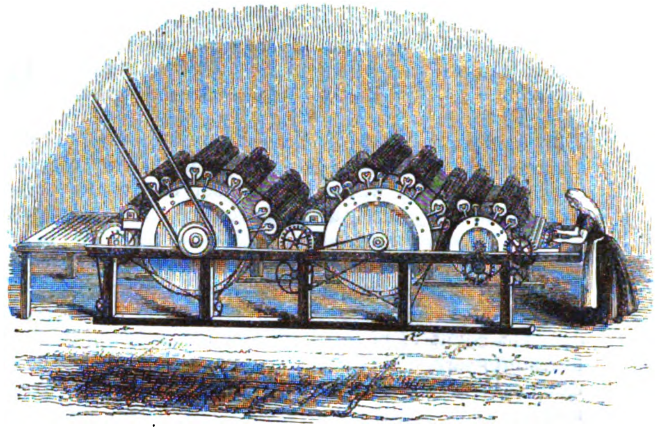
59. SHEEP IN WINTER.

60. SCENE OF THE FIRST WOOL-GROWING EXPERIMENT IN AUSTRALIA.

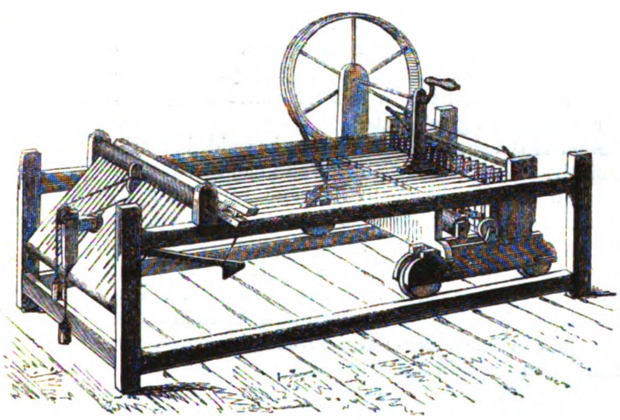


61. THE WILLY.

65. LONG WOOL-COMB.

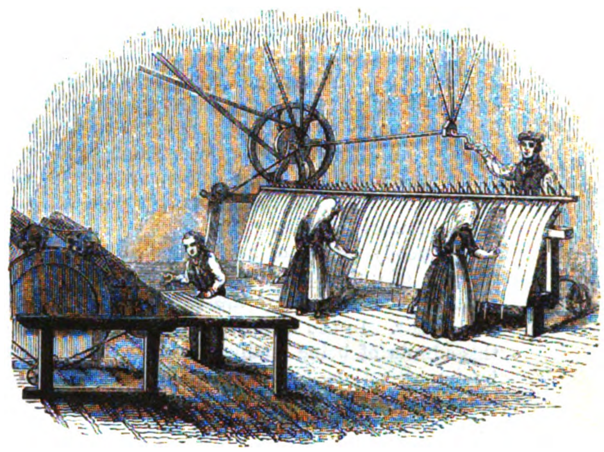


62. WOOL-CARDING ENGINE.

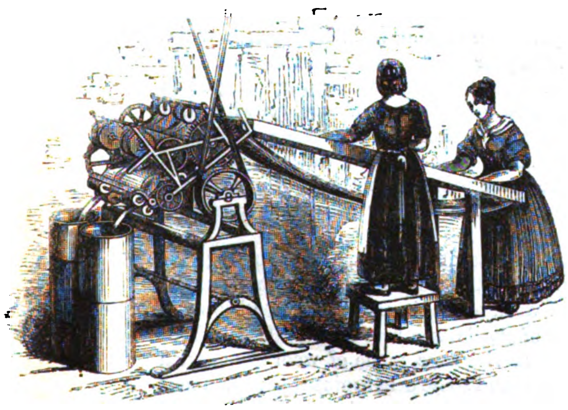


63. THE SLUBBING BILLY.

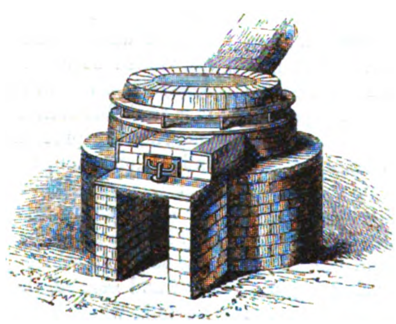
66. COMB-POST.



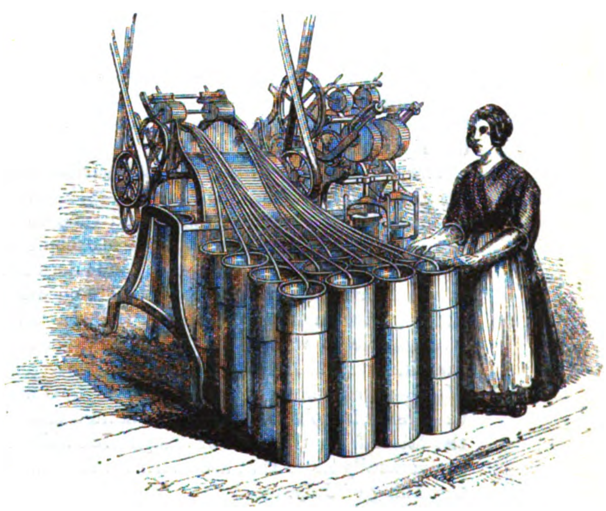
64. MODERN SLUBBING MACHINE.



68. BREAKING FRAME.



67. THE COMB POT.



69 DRAWING FRAME (8 INTO 1).

III.—WOOL.

THE woolly covering of the sheep furnishes an excellent material for various kinds of clothing; and, accordingly, we find in most countries where this animal is pastured, that the spinsters of every family are, or have been, more or less occupied with it. It is remarked that King Edward the Elder, in order to give his children a proper princely education, "set his sons to school and his daughters to *wool-work*." By wool-work is not meant the production of absurd pictures in a material which does not admit of pictorial effect, but the spinning of woollen fibres into yarn, and afterwards weaving them into some kind of cloth. At a later period the art of spinning and weaving wool rose from a domestic to a national employment; and to mark its importance and the estimation in which it was justly held, the seat assigned to the highest law officer of the crown in the House of Lords was a woolsack, which it continues to be to this day.

The Domestic Sheep (fig. 53) is supposed to have descended from the *Argali* (fig. 55), which is still found wild in the mountains of Siberia and Kamschatka. It resembles the *Mouflon*, or wild sheep of the mountains of Sardinia, Corsica, and Asia Minor. By cultivation, it gradually loses its horns, and exchanges a hairy for a woolly coat.

Wool is a peculiar modification of hair. When one of its fibres is viewed under the microscope, it presents a number of oblique lines, as many as from 2,000 to 4,000 in the length of an inch, thereby indicating a scaly surface, which, together with its curved or twisted form, fits it for *felting*, or uniting with other fibres into a kind of matted cloth, a property on which so much of the value of wool depends.

The woolly variety of hair forms the under-clothing of a large number of quadrupeds, although in the greater proportion of them it is concealed by the external coat of smooth, straight, coarse hair. In the wild sheep there is an excess of woolly hair; this admits of being modified and improved in various degrees by domestication, by choice of pasture and climate, and other means, until the original coarse wool is replaced by wool of different qualities, all of which are very superior to the original fleece, and admit of being grouped into two classes, namely, the *short* or *carding* wool, which is used in the manufacture of broadcloths, and *long* or *combing-wool*, which is used for worsteds. Each of these divisions contains a large variety of sorts, according to their fineness, the length and soundness of the staple, and other particulars. In the Great Exhibition, some choice wools from Austria excited the admiration of the trade, on account of their "substance in the staple, and fineness and elasticity of the component fibres, the spiral curves of which are close and regular, and are immediately resumed, after being obliterated by stretching the fibres,—the length of which is also considerable for wool of this *carding* quality, the most valuable for the finest descriptions of cloth."

The wool, in its natural state, is nourished by a secretion from the glands of the skin, known as the *yolk*: it also serves to mat together the fibres of the wool, and thus to form a defence for the animal against wet and cold. In some breeds the yolk is equal to about half the fleece, and as it does not add to the value of the shorn fleece, it is usually, before shearing, washed out in a running stream (fig. 56), the yolk being a true soap, and therefore soluble in water. If the yolk were left in the fleece after shearing, it would ferment, and impart a harsh quality to the wool. Wools are also known in commerce as *fleece* wools and *dead* wools, the first being obtained from the annual sheep-shearing (fig. 58), the latter from the dead or slaughtered animal. The best wools are generally those that are shorn towards the end of June or the beginning of July.

The celebrated *Merino* wool is obtained from the migratory sheep of Spain. Immense flocks of these sheep were conducted twice a year, namely, in April and October, a considerable journey to enable them to pass the summer in the mountains of the north, and the winter in the more southern plains. The excellence of the wool was supposed to be due to the equality of temperature preserved by these migrations. About the year 1765, the Merino was introduced into Saxony, and, after some years, became naturalised in that country. By this means, the Saxon breed was improved, and, in due time, the Saxon fleece was found to be superior to the Spanish. The Merino has also greatly improved the breeds of other countries, such as those of Sweden, Denmark, Prussia, &c. In Hungary, the flocks were, at one time, among the most wretched in Europe; they were kept chiefly for the sake of their milk, from which butter and cheese were obtained. The introduction of the Merino, however, with increased care in the management of the flock, so far improved the native breed that the Hungarian fleece competed with that of Silesia and of Saxony, and has excelled the Spanish Merino in every market. The Merino has had less influence on the sheep of England than on those of other countries, since the chief object of the English farmer is to fatten sheep for the market, and to regard the wool as a secondary product. The system of artificial feeding (figs. 54, 59) enables the farmer to send his sheep to market quickly; whereas if the wool be the object, the animal must be kept a long time before it arrives at maturity, and the increased value of the wool cannot be set against the disadvantage of having the sheep longer on hand. Hence the plan has been, in this country, to purchase the finer foreign wool, and to rear our sheep for the sake of the mutton. The principal demand for English wools is for flannels and for coarse cloth, such as that used for coachmen's great coats.

The introduction of the sheep into Australia has added greatly to the wealth of the colony. New South Wales had no sheep of its own, and a small flock was originally introduced from Bengal. These are described as being more like goats than sheep, on account of their coarse hairy fleece; but the climate agreed with them, and they improved, and still more so when the South Down (fig. 53) and Leicester varieties were added to the flock. In a short time, both the fleece and the carcase became doubled in value, and the introduction of the Merino still further improved the breed. It occurred to Captain (afterwards Lieutenant-Colonel) Macarthur that, if the fleece of the common Merino became finer and softer under the climate of New South Wales, it was not improbable that even the Saxony wool might be increased in value. He, therefore, imported some sheep direct from Germany, and found, after fairly testing the experiment, that if the Saxon fleece had not been improved, it was superior to any other in the colony. Fig. 60 is taken from a sketch of part of the Camden estate of Captain Macarthur. The success of these experiments has been complete. The first importation of wool from New South Wales in 1807 was 245 *lbs.*; in the year 1848, it amounted to 23,000,000 *lbs.* valued at upwards of 1,200,000*l.* The discovery of gold in Australia arrested for a time the progress of wool-growing, but it is probable that the amount of toil and expense required for securing the precious metal by direct means, will have satisfied industrious men, that the more indirect methods of agriculture and honest trade are as well or even better calculated to make a man prosperous.

The two great divisions of wool into carding and combing give rise to two distinct branches of the woollen manufacture, namely, *cloth* and *worsted*, the last word being the name of a small town in Norfolk, where this class of goods was first made. Until about thirty years ago, worsted fabrics were made of wool alone, with the exception of bombazines, and some other mixtures; but about that time, goods consisting of a worsted weft and a cotton warp came into use. In 1836, the wool of the *Alpaca*, an animal of

the Llama tribe, belonging to the mountain ranges of Peru, was introduced: this wool is of various shades of colour, is remarkably bright and lustrous, has great length of staple, and is extremely soft. It soon acquired a high rank in the worsted trade. About the same time, *Mohair*, the wool of a goat from Asia Minor, came into use, and led to the production of many beautiful fabrics, while the combination of silk with these new materials led to further varieties in articles of clothing and furniture.

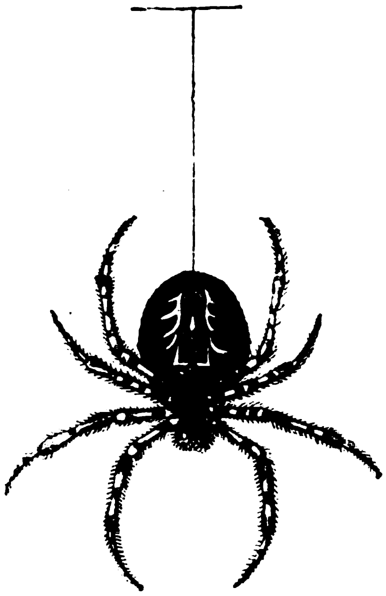
During the year ending 31st December, 1856, there were imported into the United Kingdom from British possessions out of Europe, 81,893,148 *lbs.* of sheep and lambs' wool; from other parts, 31,343,751 *lbs.* making a total of 113,236,899 *lbs.* Also of wool of the Alpaca and Llama tribe, 2,974,493 *lbs.*

First, with respect to the manufacture of broad-cloth. The three varieties of wool most in request are the German, the Australian, and the Cape, while the wools of Odessa and New Zealand are also more or less in request. Wool arrives in England in its natural state, or in the *grease*, as it is called, with the yolk and dirt adhering; or it may be in the state called *hand-washed*, in which case the sheep, previously to shearing, have been washed in a running stream as already noticed. *Scoured wools* have been scoured and cleansed after the shearing.

The first operation at the factory is called *sorting*, or dividing the wool into qualities, such as *primes*, *seconds*, and *thirds*. This is done at a table formed of horizontal bars of wood, so that on opening the fleece and separating the qualities of wool, loose dirt, &c. may fall through. The wool may then be *scoured* or washed, to get rid of the animal grease; after which it may be dyed, or the dyeing may be left until after the cloth has been woven. In the one case the cloth is said to be *wool-dyed*, and in the other, *piece-dyed*. Supposing the wool to be dyed, it is passed through the *willy*, or *twilly*—resembling the *willow* of the cotton manufacture—(fig. 61), consisting of a large wooden cylinder or cone, furnished with iron spikes, enclosed in a wooden case, also furnished with spikes. The wool is supplied to this machine by an endless web, or feeding-cloth, and passing between feeding rollers, is exposed to the action of the spiked cylinder, which, revolving rapidly, tears apart the fibres and disperses the dust and dirt through a grating below. The wool is next picked, in order to remove seeds and foreign matters, or locks of wool which have not properly taken the dye, or which belong to other sorts. The wool is next spread out on a stone floor, and sprinkled with Gallipoli or palm oil; layer being piled upon layer after each oiling. The wool is again passed through the willy, in order to mix the oil and the wool thoroughly. The wool is now ready for the *scribbler*, which is similar in principle to the cotton-carding engine (figs. 15—19). Scribbling is, however, a coarser process than carding, and its object is to form the oiled wool into a broad thin fleece or lap. Wool goes through the scribbler two, three, or four times, so that the fibres may be well opened; after which it is carded. The object of the *wool-carding engine* (fig. 62) is not to place the fibres parallel, as in the case of cotton, but to open them and make them cross each other in all directions. The large cylinders, or *card-drums*, and the small cylinders, or *urchins*, all covered with carding wires, prepare the wool, and the last cylinder, or *doffer*, which is covered with straight parallel strips of wire, allows the doffing knife to remove the wool in the form of separate slivers, each the length of the doffing-cylinder, and these fall into the plates of a plated cylinder, called the *roller-bowl*, which being partly covered with a case or shell nearly in contact with it, the slivers are rolled into cardings, and are received upon an apron at the opposite end of the machine. The cardings have next to be twisted into yarn, for which purpose a machine, founded on the spinning-jenny (fig. 31), and called the *slubbing-billy* (fig. 63), is used. It consists of a wooden frame, within which is a carriage moving upon the lower side rails, and containing a number of spindles, which are made to whirl round by means of cords, passing round the pulley of each spindle and connected with a drum, which extends the whole breadth of the carriage, and to which motion is given by turning the handle of a large wheel, which is connected by a strap with the drum. The cardings are arranged upon a slanting apron at the end of the frame, and pass under a roller, called the *billy-roller*, which presses lightly upon them. In front of this roller is a moveable rail, which, when it rests upon the cardings, prevents them from being drawn through, and when elevated prevents the cardings from being drawn forward by the retiring of the spindle-carriage. The twisting of these cardings and the winding them up on the spindles does not differ greatly from similar operations already described with the spinning-jenny. The cardings, as fast as they are produced at the carding-engine, are brought by children, and attached to the ends of the cardings resting on the sloping apron: this joining is performed by a slight lateral rolling motion of the fingers of the right hand. By the constant activity of the little pieceners, the cardings on the apron are always kept at the proper length. The slubbing-billy is now mostly superseded by the *slubbing-machine* (fig. 64), which does not greatly differ from the cotton-mule (fig. 32); but the operation of slubbing has been partially superseded by a machine called the *condenser*. The wool is now in the condition of yarn fit for weaving, and will be again noticed when we come to speak of that operation.

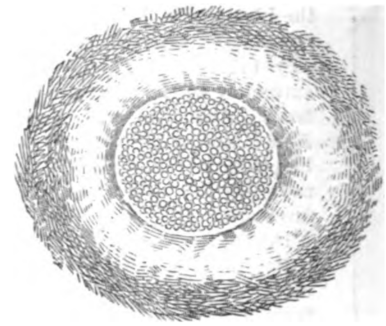
In the preparation of worsted yarn, care is taken to dispose all the fibres in parallel lines, as in the case of cotton and linen, and not, as we have seen in the case of short wool, to allow them to cross in various directions, for the purpose of enabling them to felt together in a subsequent process. The long wool is scoured, dried, and willowed, preparatory to *combing*, which is one of the distinguishing operations of long wool. The wool-comber is furnished with a couple of combs, one of which is shown in fig. 65, together with a *post* (fig. 66), to which the comb can be attached, and a small stove, called a *comb-pot* (fig. 67), for heating the teeth of the combs. The wool-comb consists of several rows of sharp steel teeth of different lengths, fixed to a wooden stock or head, covered with horn, from which proceeds a perforated handle, made to fit into certain projections in the upright post. The comb-pot is a flat iron plate, heated by means of fire or of steam, and above this is a similar plate, with sufficient space between the two to admit the teeth of the comb. The heated comb being attached to the post with the teeth upwards, the workman takes a handful of wool, sprinkles it with oil, rolls it up in his hands, and then throws one-half of it over the points of the comb; he draws it repeatedly through them, and leaves each time a few stray filaments in the comb. When the wool is thus disposed of on the comb, the latter is removed to the stove; an empty comb is taken therefrom, mounted on the post, and filled with wool as before. The man then takes both combs, sits down, and holds one of them on his knee with his left hand, and with the other comb in his right hand he introduces the teeth of one into those of the other, draws them through, and thus transfers all the wool to one comb. This process is repeated again and again, until the fibres are laid parallel. When the operation is complete, a quantity of short wool, called *noyl*, about one-eighth of the quantity employed, remains in the comb; this is removed and afterwards transferred to the short-wool manufacture. The long wool, after leaving the comb, requires to be combed again at a lower temperature before it is fit for the spinner. Wool-combing is a laborious and unhealthy occupation, and is performed in some mills by self-acting machinery. The *combing machine* was originally invented by Josué Heilmann for the cotton manufacture. A few words descriptive of the work that it does for cotton, will show its applicability to wool and flax. It combs the lock of cotton at both ends, places the fibres exactly parallel, separates the long from the short, and unites the long fibres into one sliver, and the short ones into another. Its great value is in rendering the commoner sorts of cotton available for the purpose of fine spinning.

The wool, as it is combed into slivers, is formed into narrow bundles, called *tops;* these being unrolled, the slivers are separated and thrown loosely over a pin, within reach of an attendant

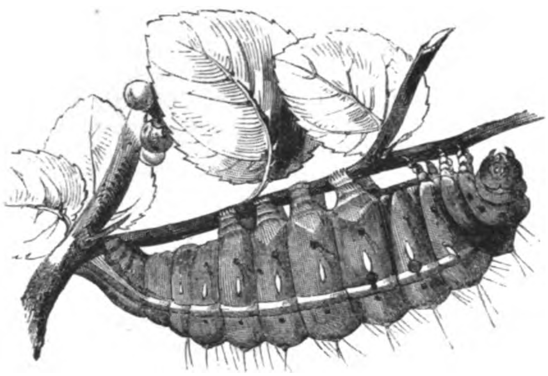


GARDEN SPIDER (*Natural size*).

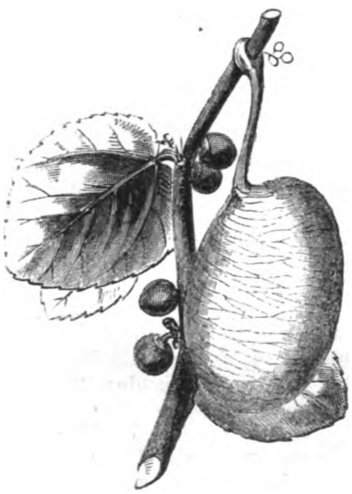
71 SPIDER'S NEST ATTACHED TO A FLAT SURFACE



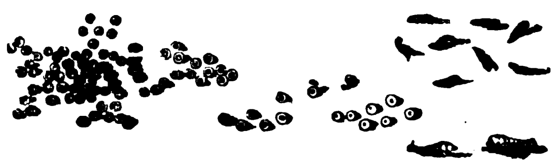
72. SPIDER'S NEST LAID OPEN.



73. THE TUSSEH SILKWORM.

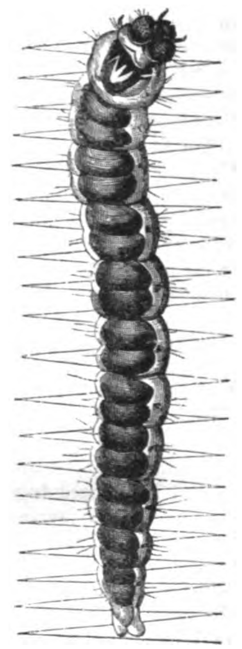


74. COCOON OF THE TUSSEH SILKWORM.



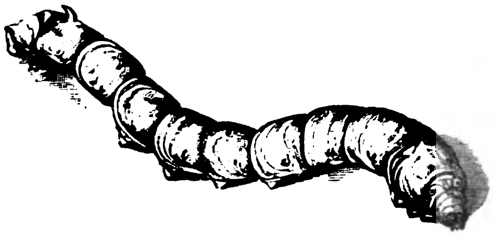
76. EGGS AND SILKWORMS IN THE FIRST AGE.

77. PROGRESSIVE GROWTH OF THE SILKWORM.

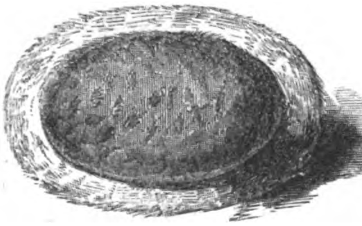


75. SILKEN LADDER SPUN BY THE GOAT-MOTH CATERPILLAR

81 THE CHRYSALIS



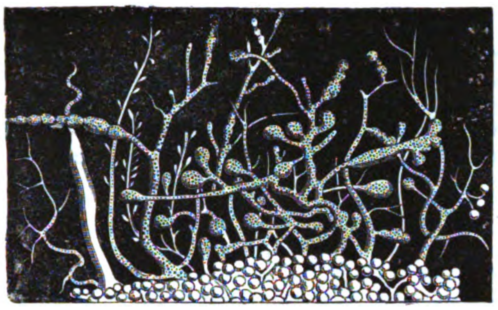
79 FULL-GROWN SILKWORM.



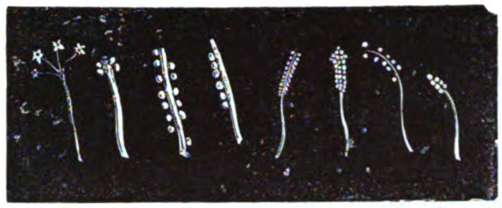
80. THE COCOON.
(*A portion of the floss silk has been removed.*)

78. SILKWORM ON MULBERRY LEAF.

82. FEMALE SILKWORM MOTH AND EGGS

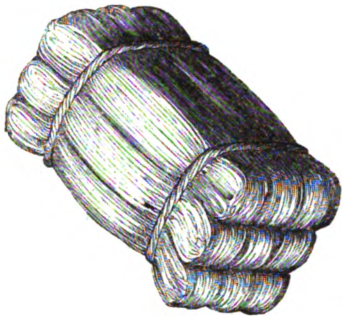


83. ADVANCED STAGE OF MUSCARDINE (*Highly magnified*).



84. EARLY STAGE OF MUSCARDINE (*Magnified*).

85. GIRL WINDING SILK

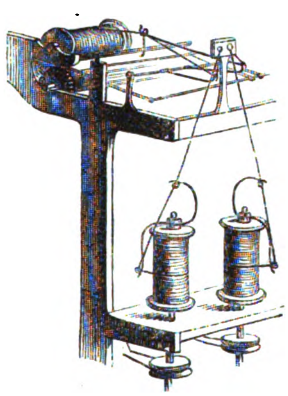


86. BOOK OF SILK FROM CHINA.

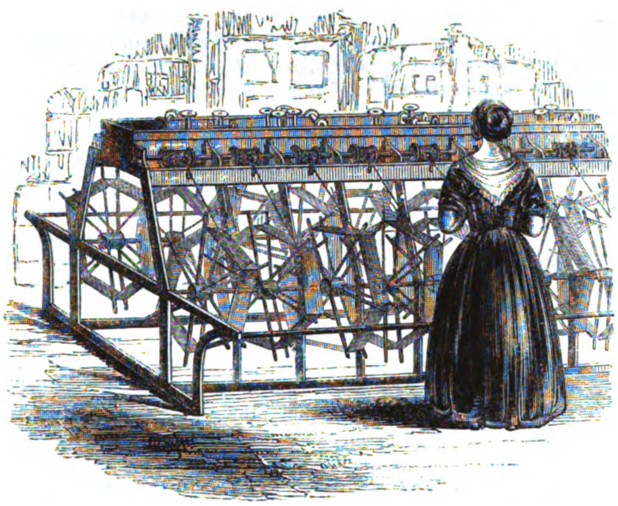
87 THE WHITE MULBERRY (*Morus alba*).

88. BOBBIN.

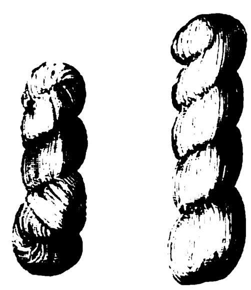
91. SLIP FROM BENGAL.



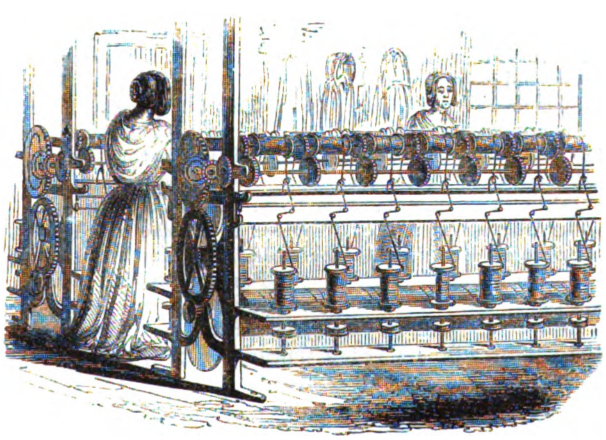
89. DOUBLING.



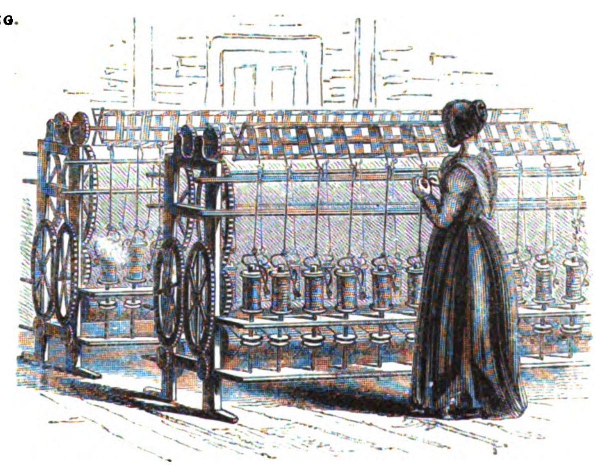
90 WINDING.



92. HANKS FROM ITALY.



93. SPINNING MACHINE.



94. DOUBLING OR THROWING MACHINE.

who, taking a sliver, spreads it flat upon a feeding-board or apron, presenting the end to the first pair of rollers of the *sliver-box*, or *breaking-frame* (fig. 68), which draw the sliver in. When it has passed half through, the end of another sliver is placed upon the middle of the first, and they are drawn through together. A third sliver is placed on the middle of the second, and in this way the short slivers are united and extended by other pairs of rollers into one long and uniform sliver, which is received into a can. A number of these are drawn into one at the drawing-frame (fig. 69); these are also received into cans, and afterwards pass through the operations of roving and spinning, which resemble in principle those operations as described under cotton.

IV.—SILK.

There are few things more wonderful in nature or in art than the mighty results which are frequently brought about by small and apparently inadequate means. Nothing can appear more insignificant than a single polype; yet, by the united efforts of millions of polypes, vast reefs of solid rock rise up in the ocean, and form clusters of islands which become clothed with luxurious vegetation, occupied by various animals, and are lastly taken possession of by man. A caterpillar, spinning from its own intestines a structure which we may term either its cradle or its grave, may also appear an insignificant object; but, when we find myriads of these caterpillars encouraged and protected by many nations of the earth, their united labours lead to results of a very surprising character.

The Chinese are the most extensive cultivators of the silkworm. From their country, the culture spread to Japan, to Tonquin, to Siam, to Hindostan, to Persia, to Greece, to Italy, and to France. We obtain supplies of silk from all these countries except Tonquin and France, the latter country consuming all that it produces. The climate of Great Britain is not adapted to the successful culture of the silkworm, nor do we receive any silk from our colonies. China affords the great supply, and this has gone on increasing. In 1830 we received 4,842 bales, and in 1857 we imported 94,612 bales from China—an increase of nearly twenty-fold. The cost of the last-named import was about 12,000,000*l.* sterling, or more than double the value of our imports in tea. There are several reasons for this prodigious increase. In 1830, our intercourse with China was through the East India Company, and our trade was restricted to a single port. Since that time the trade has been made free, and four additional Chinese ports have been opened to us. Besides this, a murrain had attacked the silkworms of Europe, which led to increased imports from China. The production of Indian silk is limited to a few districts of Bengal Proper, and the supply is very scanty, amounting in 1857 to no more than 9,011 bales. The quantity from Turkey and Persia is also very small. The silk of Persia is inferior in value to that of China, by as much as 30 per cent. The silk of the North of Italy is 60 per cent. better than that of China, and still more valuable than that of the average qualities of British Bengal. The production of any raw material which requires skill and care in the preparation, may be taken as a test of civilization; and, measured by such test, Turkey and Persia are at the bottom of the scale, Bengal comes next, China next, Italy next, and France, notwithstanding the disadvantages of climate, probably takes rank above Italy.

The insect which furnishes the most ready and available supply of silk is the caterpillar of the mulberry-tree moth (*Bombyx mori*), fig. 82, belonging to the tribe of mealy-winged nocturnal insects. The production of silk, however, is by no means confined to this insect: it is a common working material in the insect world, as well as a weapon of offence and defence. Thus, the garden spider (fig. 70) makes its web of this material; and when its labours for the season are over, deposits its eggs in a warm silken bag (fig. 72), which it attaches to a flat surface (fig. 71) in some sheltered place, where it remains throughout the winter; the warmth of the following spring being sufficient to hatch the eggs. As the spiders, like other insects, let themselves down by a silken line, so they ascend by means of the same material, often in a very ingenious manner, as in fig. 75, where a goat-moth caterpillar, having been put into a glass tumbler, escaped therefrom by means of a silken ladder, as shown in the figure. In Bengal, the nests or cocoons of the *Tusseh* silkworm (figs. 73, 74) furnish a large supply of coarse, dark-coloured silk, which is woven into a cheap durable cloth. When the larvæ are near their full size, they are too heavy to crawl in search of their food with the back upwards, as is usual with most caterpillars; but traverse the small branches, suspended by the feet. The cocoon is of an oval shape, attached to a branch by a thick, strong, silken cord. The *Arindy* silkworm, also a native of Bengal, produces an abundant supply of delicate, glossy silk, which does not admit of being unwound from the cocoons, and is, therefore, combed, carded, and spun like cotton: the thread is woven into a coarse kind of white cloth, of so durable a texture, that a person can scarcely in his lifetime wear out a garment made of it. There are silk-producing insects in other parts of the world, which furnish local supplies of silk, as in South America, where cocoons of grey silk, eight inches in length, are said to be obtained. None of these varieties of silk, however, combine so many valuable properties as that of the ordinary silkworm.

The eggs of the silkworm moth (fig. 76) are smaller than grains of mustard seed: they are slightly flattened; and are at first of a yellowish colour, but change in a few days to a slate-colour. In temperate climates, they are kept through the winter until the mulberry-tree puts forth its leaves in the spring. The white-fruited mulberry-tree (*Morus alba*), fig. 87, a native of China, is the proper food for the silk-worm; and it is remarkable that, while other trees nourish innumerable tribes of insects, the mulberry-tree is seldom attacked by any but this one. The worms, when first hatched, are about a quarter of an inch long, and of a dark colour (fig. 76): they must be fed on young and tender leaves, and if their food be properly supplied, they will remain contentedly upon it, and manifest no roving propensities. In the course of eight days, the creature rapidly increases in size, so that its skin has become too small for its body: it now remains three days without food, during which a secretion forms under the skin—on the surface of the new skin, in fact; and this enables the caterpillar to cast off the old one. But it also assists itself in this object by means of silken lines, which it attaches to adjacent objects. These hold the old skin tightly, and the animal creeps out of it; the whole of the covering of the body, including that of the feet and of the jaws, being cast off. The moulted worm is of a pale colour and wrinkled: it now recovers its appetite, and grows so rapidly that the new skin is filled out, and, in the course of five days, another moult is required. Four of these moults and renewals of the skin bring the caterpillar to its full size (see figs. 77, 78, 79), when it is nearly three inches long, and consists of twelve membranous rings, which contract and elongate with the motion of the body. There are eight pairs of legs, the first three pairs being covered with a shelly or scaly substance, which also invests the head. The mandibles are strong, and are indented like a saw, and are in constant use at this time, the appetite of the animal being voracious. Beneath the jaw are two small orifices through which the insect draws its silken lines. The silk is a yellow transparent gum, secreted in

slender vessels, and wound, as it were, upon a couple of spindles within the stomach; which vessels, if unfolded, would measure ten inches in length. Along the sides of the body are nine pairs of spiracles or breathing holes: near the mouth are seven small eyes, but the two spots higher up, which so much resemble eyes (fig. 79), are only portions of the skull. When at maturity, the caterpillar is of a rich golden hue: it then leaves off eating, and selects a corner in which to spin its cocoon. It first forms a loose structure of floss-silk, and within it the closer texture of its nest of an oval shape (fig. 80): the caterpillar remains working within it until it gradually disappears; it takes no food, but, constantly spinning its beautiful winding-sheet, its body diminishes one half, and the cocoon being complete, it once more changes its skin and becomes transformed into an apparently lifeless chrysalis or aurelia (fig. 81), with a smooth brown skin, and pointed at one end. It remains in this state for two or three weeks, and then emerges in the form of a perfect winged insect, the silk-moth (fig. 82). In order to escape from the cocoon, it moistens the interior with a liquid which dissolves the gum that holds the fibres together, and, pushing them aside, escapes. The perfect insect has but a short life, and only one object to accomplish; namely, to provide for the continuation of the species. She lays her eggs in the course of two or three days, and then dies.

The silkworm is a delicate insect, and requires careful nursing; it is liable to many diseases, among which is one characterised by the formation of a minute cryptogamous plant or mildew within the body of the living insect. When it is exposed to damp and fermenting food and litter, there forms in the fatty matter of its body a number of sporules, supported by minute stems, specimens of which, highly magnified, are represented in fig. 84. These increase to such an extent that the vegetation pierces the skin, and imparts a general mealy character to the body (fig. 83); it soon ripens its seed, which floats in the air to every part of the nursery, inoculating the healthy worms; the first patient soon dies, and its dead body continues to be a source of contagion. The disease is called *muscardine* in France, from the name of a sugar-plum which it somewhat resembles. The Italians name it *calcinetto*, from the chalky or mealy appearance of the skin. A solution of blue vitriol applied to the woodwork, frames, &c. of the nursery, is useful in destroying the seeds of the fungus; but the best preservatives are rigid cleanliness, and attention to ventilation. The Government of France have, at different times, offered premiums for the best modes of curing and preventing disease in the silkworms; and, at the time we were writing the first edition of this work (1858), the Austrian Government placed a sum of money at the disposal of the Central Sericultural Society of Italy, with a similar object. Some idea of the extent of the silk-growing operations in France may be formed from the fact that, in the department of the Drome, upwards of 3,000,000 mulberry-trees are required to supply the food of the worms.

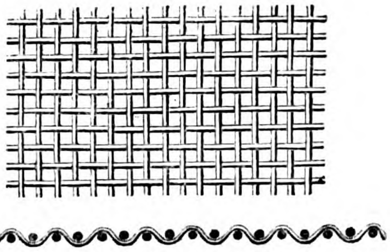
When the crop of cocoons is gathered in, about one-sixtieth part is set aside for the production of eggs, the finest cocoons being selected for the purpose. The female cocoons are heavier and rounder than the male, and a due proportion of each sort is taken: they are preserved in a dry room. The main crop of cocoons is next sorted according to their qualities, the vitality of the enclosed chrysalis is destroyed by heat, the floss silk is removed, and the cocoons, being immersed in warm water to soften the gum, a number of the loose ends are twisted together, passed through a metal loop, which rubs off dirt and impurities, and then passed on to the reel, which has a shifting side motion, so that the thread of one revolution may not overlay that of another; for if allowed to do so, the threads would be glued together before the gum had time to harden in the air. When a single filament breaks or comes to an end, its place is supplied by a new one, that the united thread may be of equal thickness. The cocoons are not entirely wound off, but the husk containing the chrysalis is added to the floss silk under the name of *waste*. Eleven or twelve pounds of cocoons yield one pound of silk, from 200 to 250 cocoons weighing one pound, so that not less than 2,817 are required for a pound of silk. This estimate refers to the ordinary cocoon, which is of a bright yellow colour. Major Bronski, of Bordeaux, has succeeded, under improved cultivation on a plan of his own, in obtaining a race of silkworms not subject to disease, producing large and equal-sized cocoons of a pure *white* colour, the silk of which is equal in all its length, strong and lustrous, and of an average length per cocoon of 1,154 yards.

The reeled silk is made up into hanks, the forms of which, as well as the qualities, differ in various countries, as will be seen by referring to the figures 86, 91 and 92. When the raw silk reaches the factory, it passes through a number of processes which vary with its ultimate destination. It is *wound* and *cleaned* for weaving into Bandana handkerchiefs, and is further *bleached* for gauze and similar fabrics. With this amount of preparation it is called *dumb singles;* but when wound, cleaned, and *thrown*, it is called *thrown singles*, and is used for ribbons and common silks. If wound, cleaned, doubled and thrown, and *twisted* in one direction, it becomes *tram*, and forms the woof or shoot of *gros de Naples*, velvets, and flowered silks. If wound, cleaned, spun, doubled, and thrown, so as to resemble the strand of a rope, it is called *organzine*, and is used for warp. When the natural gum of the silk is left in it, it is called *hard;* but if removed by *scouring*, it becomes *soft*.

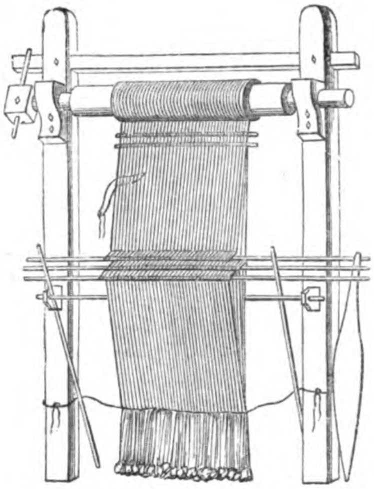
The first operation is to open the hanks, and stretch them upon light six-sided reels of lance wood, called *swifts* (fig. 90), from which they are transferred to bobbins, arrangements being made to wind the filament upon them in a spiral or oblique direction, to prevent lateral adhesion (fig. 88). The bobbins thus filled are removed to a *cleaning* or *picking* machine, where the filament from each bobbin is passed over a glass or iron guide-rod, and then drawn through a brush or cleaner, in order to separate impurities. Each filament is dragged from its bobbin through the cleaner to another bobbin, and, should a knot or a mote occur, the filament is prevented from passing through an eye in a bar of metal, which bar becomes depressed, and the bobbin is thereby lifted off the friction roller, from which it receives motion; the attendant, noticing this, removes the impediment, and again sets the bobbin in motion. The next process is *spinning*, and this consists not in the twisting together of short fibres as in the case of cotton, flax, or wool, but of the continuous filament of clean silk. The spinning is accomplished by means of the bobbin and fly (fig. 93). Where a number of filaments are twisted together, the process is called *doubling* or *throwing*, which last term appears to have been derived from the rope-maker, who *throws* twists into his rope. In doubling, the silk filaments are arranged parallel on a horizontal wheel, and passed through the eye or loop of a rotating fly (fig. 94), by the rotation of which a number of filaments are twisted together. The twist varies according to the uses intended. In spinning single filaments, the twist is to the right; for tram, the filaments are doubled and then twisted to the right; for organzine, the filament is twisted to the left, then doubled and twisted to the right, and so on, the texture of various woven fabrics depending on these variations.

Fig. 89 represents a contrivance in the doubling frame for stopping the bobbin, should one of the filaments break. If two threads are to be doubled, each thread is passed under the hook of a wire which it supports, and, should the thread break, the wire falls down on a lever, which it depresses, and its opposite end arrests the motion of a bobbin.

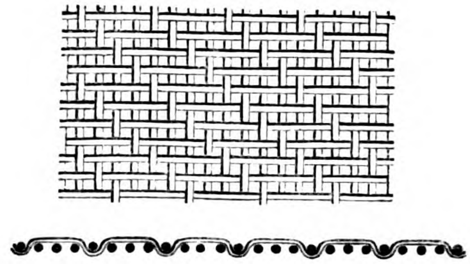
Some of the heavier descriptions of silk thread, such as sewing or fringing thread, are prepared at a throstle frame, similar to that used for cotton (see fig. 29); the floss silk, and the refuse of throwing, are worked into yarns for cheap shawls and handkerchiefs. The waste is sent to the spinner in small balls, which are sorted, heckled, cut up into short lengths, purified by boiling and, lastly, carded and formed into yarn by processes similar to those adopted for cotton, or, instead of cutting up the waste, it may be drawn into slivers, by a modification of the machinery used for flax.



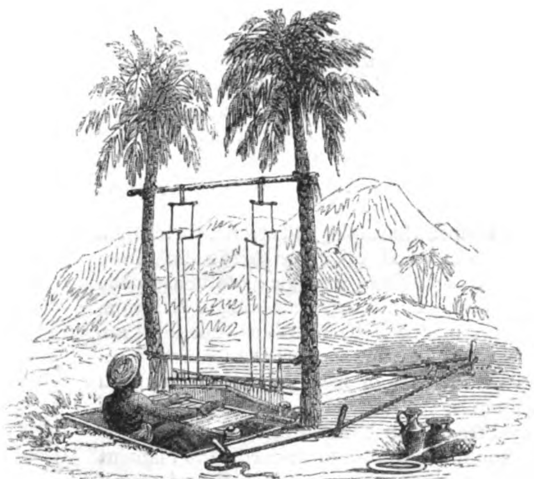
95. PLAIN WEAVING.



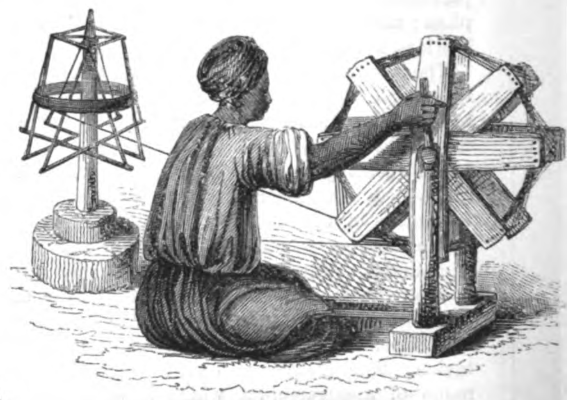
97. ANCIENT LOOM.



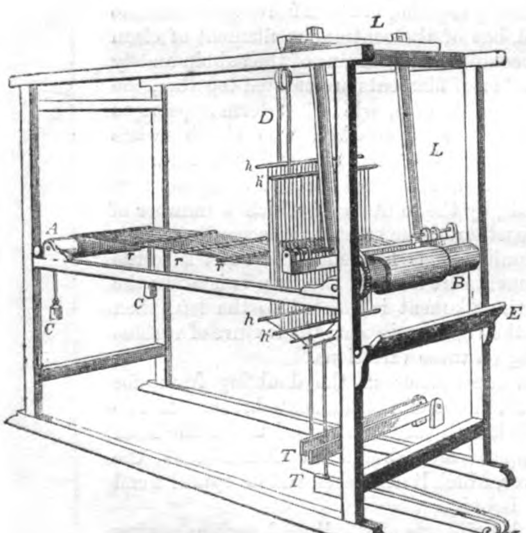
96. TWILLED WEAVING.



98. HINDU WEAVER.

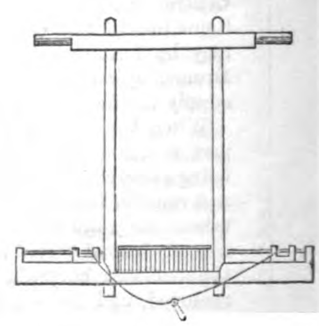


100. ORIENTAL WEAVING.

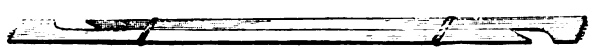


101. THE COMMON LOOM.

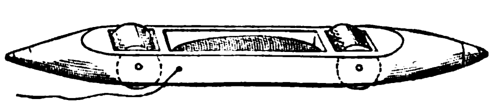
99. MODERN EGYPTIAN WEAVER.



102. BATTEN, REED, AND SHUTTLE-RACE.

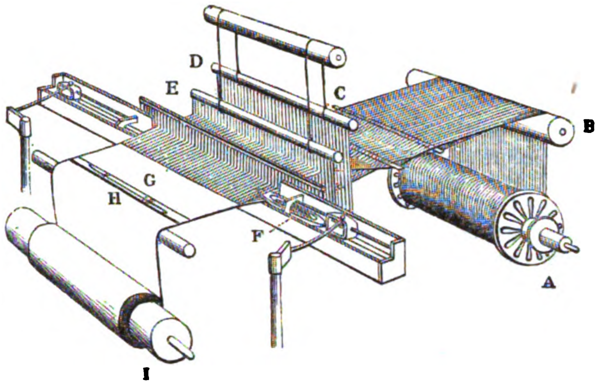


105. TEMPLES.

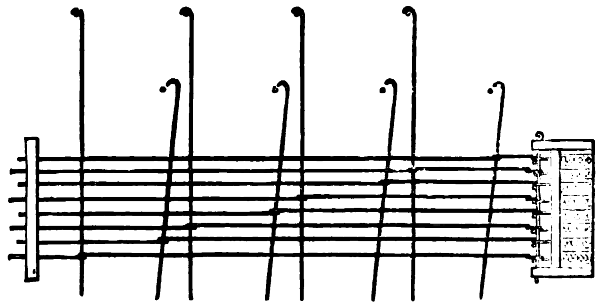


103. THE SHUTTLE.

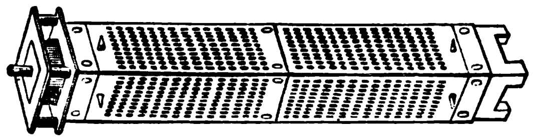
104. THE FLY-SHUTTLE.



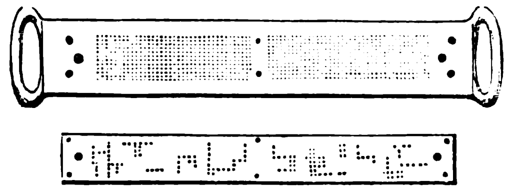
106. PRINCIPAL PARTS OF A POWER-LOOM.



107 PRINCIPLE OF THE JACQUARD APPARATUS.

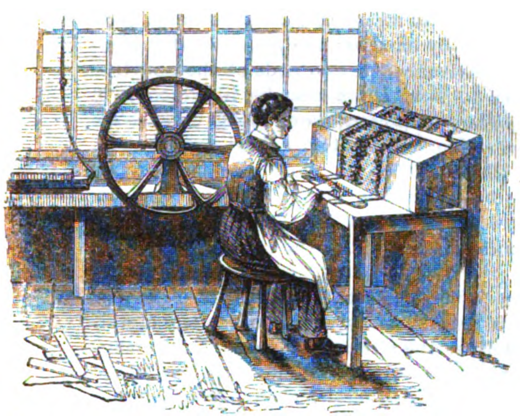


108. JACQUARD DRUM.

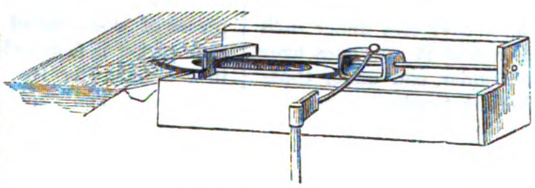


109. PERFORATED PLATE AND CARD.

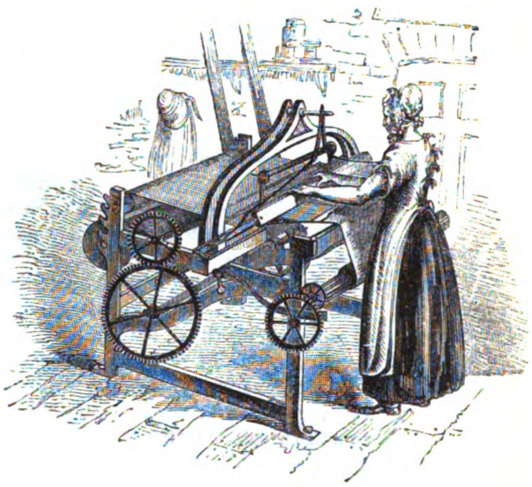
110. JACQUARD NEEDLE.



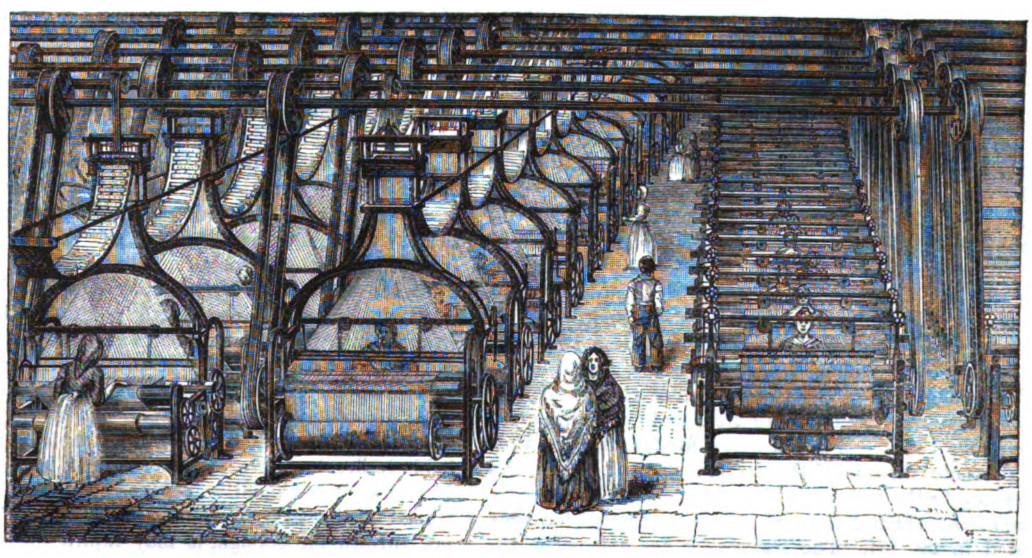
111. JACQUARD CARD-MAKING MACHINE.



112. THE SHED.



113. POWER-LOOM.—(*Cotton.*)



114. ACKROYD'S LOOM-SHED AT HALIFAX.—(*Worsted Goods.*)

V.—WEAVING.

Weaving was practised in the earliest times: it is mentioned by Moses (Exod. xxxv. 35) as one of the arts taught by those whom the Almighty had filled with wisdom of heart, "to work all manner of work, of the embroiderer in blue, and in purple, in scarlet, and in fine linen, and of the weaver." The fine linen of ancient Egypt deserved its high character, as we know from the best judges of the present day, who have had opportunities of inspecting it in the mummy cloths which have been so curiously preserved during several thousand years. It is described as being close and firm, yet very elastic; and the yarn, both of the warp and of the woof, remarkably even and well spun. In one specimen the thread of the warp was double, consisting of two fine threads twisted together; the woof was single. In other specimens the warp had three, and even four times the number of threads in an inch that the woof had. Some of the finest of these mummy cloths appear to be made of yarn of about 100 hanks to the pound, with 140 threads in the inch in the warp, and about 64 in the weft.

If we examine a piece of cloth produced by what is called *plain weaving*, it will be found to consist of two distinct threads or yarns, which traverse the *web*, as the piece of cloth is called, in opposite directions, at right angles to each other. Those threads which form the length of the web, are called the *warp*, and they extend from one end of the piece to the other. The thread or yarn, which runs across the web, is called the *weft* or *woof*. This may consist of one thread continued through the whole piece of cloth, passing alternately over and under each yarn of the warp, until it arrives at the outside yarn, when it passes round that yarn, and returns back over and under each yarn as before; but in such a manner that it now goes over those yarns which it previously passed under, and under those yarns which it before passed over, thereby firmly weaving the warp together. Fig. 95 shows the anatomy of a fragment of cloth produced by plain weaving. Variety is produced by causing every third, fourth, fifth, or sixth, &c., threads to cross each other, as in *twilled weaving*, fig. 96, where the same thread of weft remains *flushed*, or disengaged from the warp, while passing *over* three threads, and is held down by passing *under* the fourth thread. Ordinary calico, linen, &c., are produced by plain weaving; while satin, bombazine, kerseymere, &c., are the products of twilled; and to distinguish them from the former, they are called *twills* or *tweels*.

It is usual in modern weaving to arrange the warp horizontally; but in the ancient loom, it was suspended vertically, as in fig. 97, with stones suspended at the bottom for keeping the threads stretched. In the modern *Egyptian loom*, fig. 99, the warp is arranged nearly vertically, terminating in a weight for keeping it stretched. Fig. 100 represents an *Oriental winder* preparing the warp threads for the weaver. The Hindoo loom, fig. 98, is also of a very primitive character. It consists of two bamboo rollers, on one of which the warp is wound, and on the other the woven fabric. The threads of the warp are alternately raised by a pair of *healds*, and the weft is inserted by a kind of long netting needle. The Hindoo carries this rude apparatus to a couple of trees, which may afford some shelter, where he digs a hole for a seat, and stretches his warp, by fastening two bamboo rollers at a proper distance from each other, with pins in the turf; the healds he attaches to a branch of the tree or to a bamboo pole stretching from tree to tree, and, with his great toes inserted into two loops which serve for treadles, he thus raises the alternate threads of the warp, inserts the weft, and drives it close up to the web with his long shuttle.

The *common loom*, which has been in use in Europe for ages, is represented in fig. 101. The framework has somewhat the appearance of a four-post bedstead. At one end is the *beam* or *yarn-roll*, A, on which the warp threads are wound; while at the other end is the *cloth-beam*, B, for winding the web. As the web is wound on the cloth-beam, a portion of the warp is wound off the warp-beam, the whole being kept stretched by means of weights, C. The extended threads of the warp are prevented from becoming entangled by means of three flat rods, *r*, *r*, *r*, placed between the alternate threads of the warp. The alternate threads of the warp are raised to admit the shuttle by means of *healds*, *h*, *h'*, consisting of a number of twines looped in the middle, through which the yarns of the warp are drawn. There are two healds, one of which receives every alternate thread of the warp, and the other the intermediate threads. These healds are so united by means of a rope and pulley, D, that the lowering of one causes the other to rise. The warp is also made to pass through the dents or teeth of an instrument called the *reed*, which is set in a movable swing frame, called the *lathe*, *lay*, or *batten*, L (shown separately in fig. 102), since it beats home the weft to the web. At the bottom of this frame is a kind of shelf, called the *shuttle-race*, along which is thrown the *shuttle*, a small boat-shaped piece of wood, containing in a hollow in the middle the bobbin of yarn, the unwinding of which supplies the weft. At the side of the shuttle is a small hole, through which the yarn runs freely as the shuttle moves along. The motion of the shuttle is sometimes assisted by means of rollers, as in fig. 103. The shuttle may be thrown by hand, or the *fly-shuttle* (fig. 104) may be used. In this contrivance the two ends of the shuttle-race are closed up, so as to form short troughs, in which two pieces of wood, called *pickers* or *peckers*, move along wires. To each picker is fastened a string, and the two strings meet loosely in a handle, (fig. 102,) which is held in the right hand of the weaver. When the shuttle is in one of the troughs, a smart jerk or pull at the picker projects it along the shuttle-race into the opposite trough, while another jerk in the contrary direction brings it back again.

Supposing the weaver to be in his seat (E, fig. 101), he begins work by pressing upon a treadle, T, by which means one of the healds is lowered, and with it the alternate threads of the warp, which pass through its loops. At the same time, the other heald, with its threads, is raised, thereby leaving between the two divisions of the warp a space, called the *shed*, fig. 112, for the passage of the shuttle. For every thread of weft thrown across the warp, the weaver has three things to do: *first*, to press down one of the treadles so as to form the shed; *secondly*, to throw the shuttle across the warp; *thirdly*, to drive the thread of weft close up to the web, by means of the batten, fig. 102, which he guides with the left hand. A thread of weft being thus formed, a second thread has to be thrown in the opposite direction, for which purpose the other treadle must be depressed so that the warp threads, which were before elevated, are now lowered. As the weaving proceeds, the finished cloth is wound upon the cloth-beam, by turning a handle at the side; the beam being prevented from slipping by means of a ratchet wheel. The cloth is kept extended in breadth by two pieces of wood called *temples*, fig. 105: these are furnished with points at the ends, which are inserted into the edge or selvage of the cloth at either side.

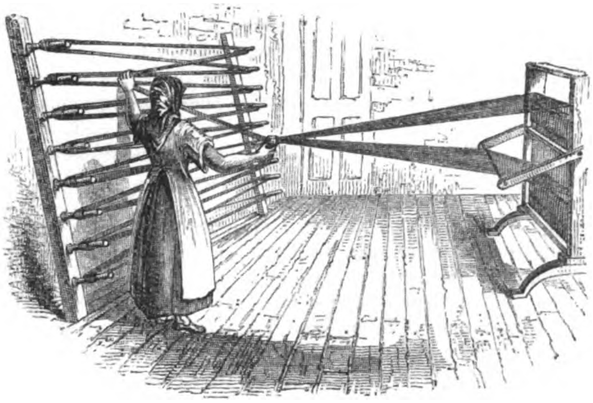
Weaving is an easy operation: a little care is required not to depress the treadles too far or too suddenly, or some of the warp threads may be broken, and much time be lost in repairing them. The friction of the dents of the reed renders the threads liable to break. Care is also required in throwing the shuttle. If thrown too violently, it may recoil, and, by slackening the thread of the weft, injure the appearance of the fabric; and if not thrown far enough, it may injure the warp threads. The

batten must also be brought up against the shoot with an equal degree of force at every stroke; otherwise the cloth will not be of uniform thickness, and the degree of force with which the batten is brought home must vary considerably, according as the goods are coarse and thick, or fine and light.

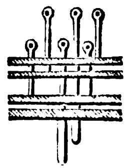
The labours of the hand-loom weaver long since proved as inadequate to satisfy the demand for woven goods, as the old spinning-wheel did to supply the yarn. It had long been a mechanical problem to weave by machinery, and many attempts were made to solve it, among which must be noticed the invention of Dr. Cartwright. This gentleman had a natural genius for mechanical construction; and although not educated as a mechanician, he could not resist his natural impulse to invent. His attention was excited by the success of Arkwright's spinning machinery; and happening, in the summer of 1784, to hear a Manchester man remark, that on the expiration of Arkwright's patents, so much cotton would be spun that hands would not be found to weave it, Cartwright remarked that Arkwright must set his wits to work and contrive a weaving mill. The possibility of weaving by machinery was denied; but the good doctor was so impressed with the idea, that he set to work, and, with the assistance of a carpenter and a smith, produced his loom. He then got a weaver to put in the warp, and succeeded in weaving by its means a piece of sail-cloth. In this first attempt too much power was used. "The warp," says the doctor, "was placed perpendicularly; the reed fell with a force of at least half a hundredweight; and the springs which threw the shuttle were strong enough to have thrown a congreve-rocket: in short, it required the strength of two powerful men to work the machine at a slow rate and only for a short time." This rude beginning was patented in 1787: and in following it up with numerous improvements the inventor was subjected to loss of property, and vexation of mind, consequent on the determined opposition of the operative weavers; until at length it was generally adopted as being as necessary in its way to the prosperity of the country as Arkwright's machinery itself. We now see it at work thousands in number under a single roof, as in Ackroyd's loom-shed, fig. 114, where the restless activity of the shuttles, and the other moving parts, so completely occupy the air with their vibrations, as to render speech and hearing useless, at least to a stranger who may visit the place. Here we see beautiful fabrics, as it were, producing themselves; the presiding mind which directs the whole not being apparent to the casual visitor; while the unskilled attendant takes the charge of two or three of these looms, and should any one of them go wrong, or should the shuttle require a new cop, stops that particular loom for an instant, supplies the defect, and sets it rattling on again. In some cases the services of the attendant are not even required; for the loom itself, should a thread break, or the shuttle be run out, will stop itself, and ring a bell to give notice that it has left off work. Nor is it upon plain weaving alone that these wonderful automatons are so active. In this same Ackroyd's loom-shed we see beautiful and complicated patterns growing before our eyes, and are half disposed to attribute to the machine itself a portion of that intelligence which produced it and set it going.

The essential parts of a power loom, detached from their framing, are shown in fig. 106. The warp is wound round the beam, A, and passing up over a roller, B, is carried through a couple of healds, D E, which form the shed for the passage of the shuttle, F, which is driven along the shuttle-race by a kind of hammer, worked by a lever, moving through a small arc of a circle. The finished cloth, G, kept stretched by the temples, H, is wound upon the cloth-beam, I. In such an arrangement, five distinct actions are performed by steam-power; each loom being connected by an endless band with the shafting overhead (see fig. 114), which is driven round by the steam-engine of the establishment. Of the five actions referred to, the *first* is to raise and depress the alternate threads of the warp so as to form the shed, fig. 112. *Secondly*, to throw the shuttle. *Thirdly*, to drive up each thread of weft with the batten. *Fourthly*, to unwind the warp from the warp beam. *Fifthly*, to wind the woven material on the cloth roller. To these may be added a *sixth;* the stopping the loom on the breaking of a thread, or when the shuttle traps, that is, sticks in its course through the thread, or when the shuttle becomes empty. In any one of these emergencies, a lever is set in motion, which thrusts aside the strap or endless band from off the pulley which turns the loom, to a loose pulley at the side, where it continues to revolve without acting on the loom.

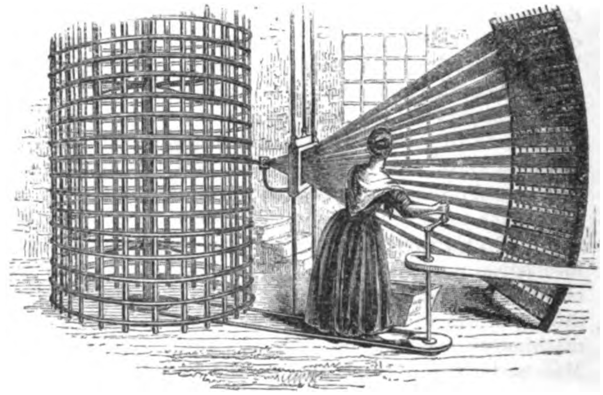
The weaving of patterns by machinery brings us to speak of the beautiful *Jacquard apparatus*, which is an addition to the loom, for raising certain threads of the warp in a certain predetermined order; so that on throwing the weft of one colour, or shuttles each containing a different colour in a certain prescribed order, a pattern shall be produced. We hope to make this more intelligible as we proceed. Before Jacquard's invention, a clumsy apparatus, called the *Draw-boy*, was in use in pattern-weaving. Jacquard was originally a straw-hat manufacturer of Lyons, in France. His dormant mechanical genius was excited by an advertisement offering a reward to any one who could produce a net by machinery. He produced such a machine, and, with the modesty or indifference of an original mind, threw his invention aside as soon as he had perfected it. By some accident a net woven by this machine was shown to some persons in authority: the Prefect of Lyons sent for the inventor, and a new machine was ordered to be constructed. In the course of three weeks this was completed and was laid before the Prefect, who, on striking a given part of the machine with his foot, saw to his surprise a new mesh added to the net. Napoleon I., who, about this time, was the liberal patron of any invention which was likely to injure the commerce of his unconquered and unconquerable rival, Great Britain, sent for Jacquard to Paris. On his arrival there, he was requested to deposit his machine at the *Conservatoire des Arts et Métiers*. This was accordingly done, and the machine was favourably reported on, whereupon the Emperor sent for the inventor, and at first sight of him called out: "Are you the man who can perform the impossibility of tying a knot in a stretched string?" In answer to this strange question, the inventor produced his machine, and formed the meshes by tying the strings, where they crossed, into hard knots, after the common manner of net-making. Napoleon, as usual, catching at a glance the talent of the man, and seeing what he was fit for, sent him to examine a loom employed in the production of articles for the use of the court, on which from 20,000 to 30,000 francs had been already expended. This loom, based on an idea of the celebrated mechanician, Vaucanson, was for the production of patterns by machinery. Jacquard undertook to produce the desired result by simpler means, and accordingly he invented the celebrated apparatus which bears his name. He was rewarded by the Government with a pension, and was permitted to return to Lyons. No sooner, however, did he make his apparatus known, than the usual fate of inventors awaited him. He experienced the most violent opposition from those whom his invention was best calculated to serve: on three occasions he narrowly escaped with his life, and during the political troubles of France his machine was condemned by the town council of Lyons: it was brought out into the market-place, broken to pieces, and its inventor covered with ignominy. In the course of a few years, however, when other countries had appropriated this beautiful invention, and by its means were rivalling the choicest productions of Lyons, the Lyonnese saw their error, and the much-despised apparatus was soon brought into active operation in all the silk, worsted, and muslin manufactories of the country. The Lyonnese sought to atone for their ingratitude by means of a memorial to their persecuted townsman: this was a woven portrait of Jacquard, representing him in his workshop, surrounded by his implements, "planning the construction of that beautiful machinery which, now in increased perfection, returns this testimony to the genius of its inventor." This piece of Jacquard weaving is spoken of as a very wonderful performance, on account of the



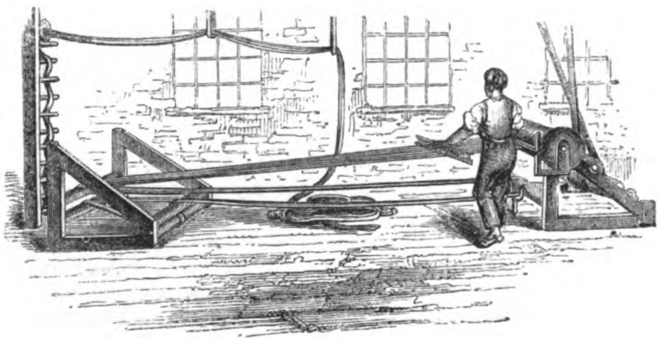
115. WARPING FRAME.—(*Woollen Yarn.*)



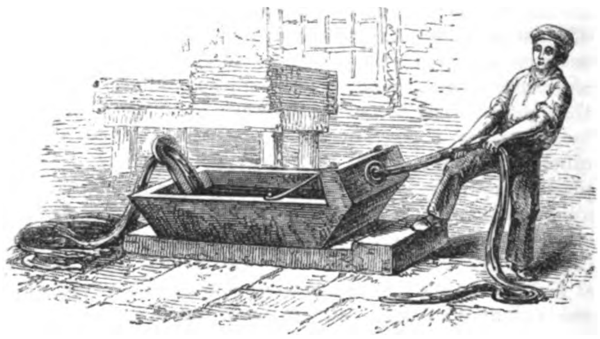
117 HECK.



116. WARPING MILL.

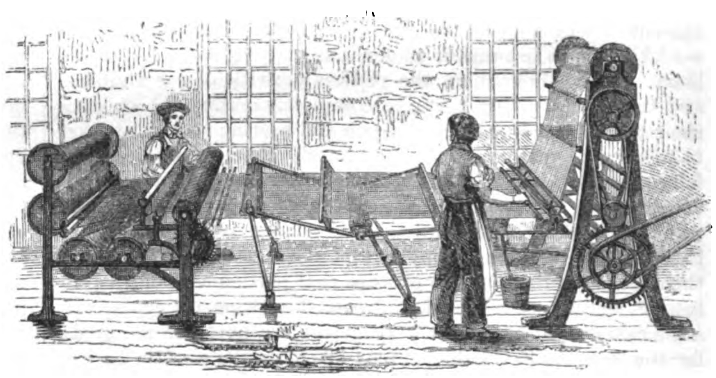


118. BEAMING.—(*Cotton Yarn.*)

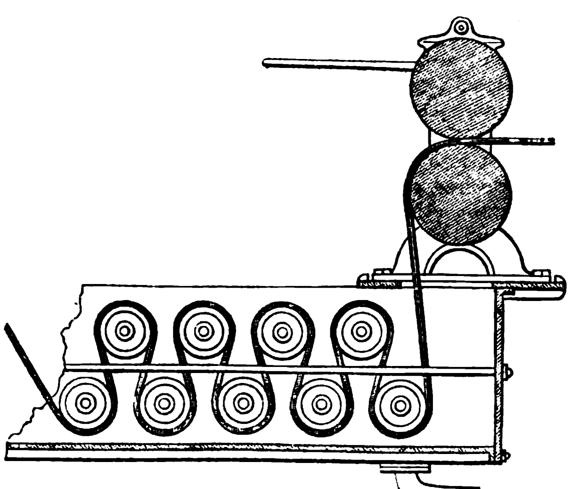


119. SIZING.—(*Woollen Yarn.*)

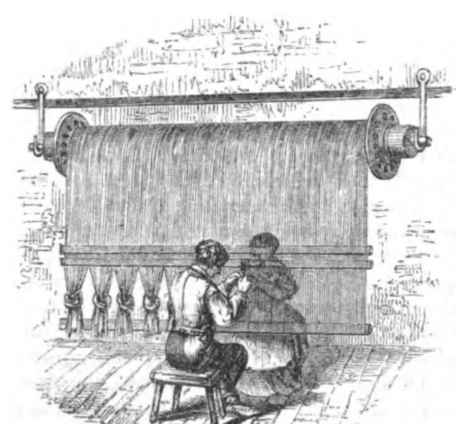
120. SCOURING WORSTED YARNS.



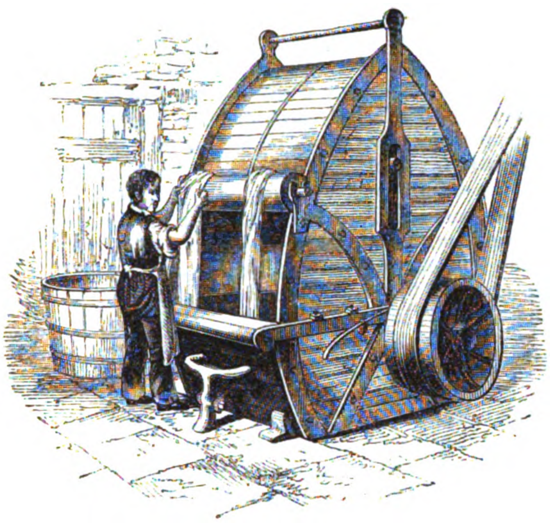
121. DRESSING AND SIZING.—(*Cotton Yarn.*)



122. SIZING MACHINE.

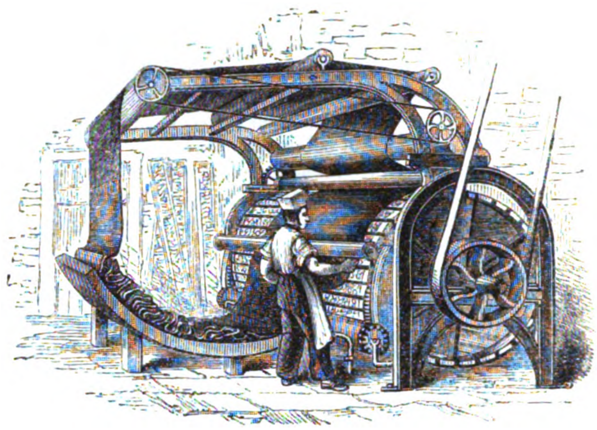


123. DRAWING IN.—(*Woollen Yarn.*)

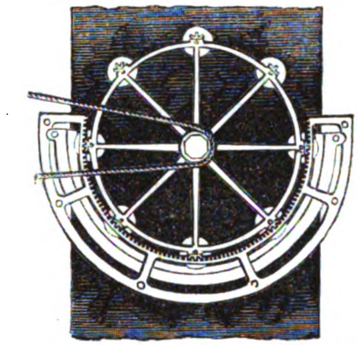


124. SCOURING MACHINE.

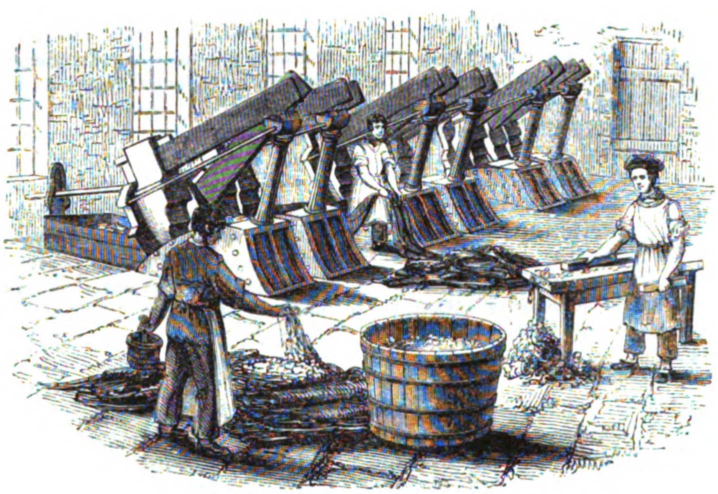
125. THE TEAZLE (*Dipsacus fullonum*).



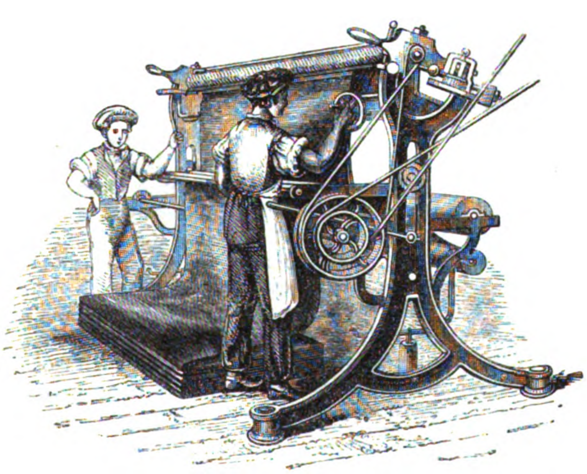
126. GIG-MILL FOR TEAZLING CLOTH.



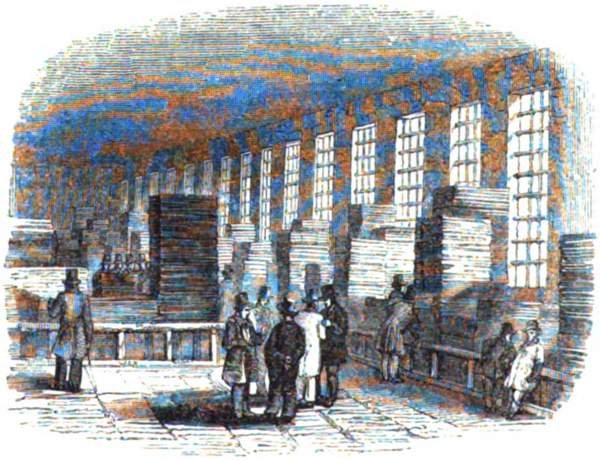
127. SHEARING MACHINE.



128. FULLING STOCKS.



129. BROAD-PERPETUAL, FOR SHEARING CLOTH.



130. INTERIOR OF CLOTH HALL, LEEDS.

fineness of the work (there being 1,000 threads in each square inch both of the warp and of the weft) and the mechanical difficulties of the undertaking; we should be better pleased if such performances as these were impossible. It is no merit to accomplish with difficulty in the wrong material that which can be effected with ease in the right. A portrait of Jacquard in oil, or a statue in stone or marble, is a legitimate performance; but a portrait woven in a silk handkerchief, whether easy or difficult of performance, is in false taste. A portrait is not meant to be folded up or crumpled in the hand, but to be exposed constantly to view on a rigid surface and in a vertical position. To this end, freedom of expression, bold handling, and judicious laying on of colour, are requisite; none of which can be given by purely mechanical means, least of all by the loom; nor can they be produced by the needle, so that on various grounds we object to the representation of the human form, or of animals, or landscapes in needlework, in worsted work, or any material not recognised by the true artist.

The Jacquard apparatus is attached to the top of the loom in a line with the healds, so as to act upon the warp threads. It must be understood that in figure-weaving, in addition to the ordinary play of the warp, for the formation of the ground of the web, all those threads which must rise at the same moment in order to produce the pattern, have their proper healds. In the draw-loom these were raised by means of cords, which grouped them together in a system, so as to be raised in the order and at the time required by the pattern. In the Jacquard apparatus, the warp threads are raised by a number of wires, arranged in rows, each wire bent at top into a hook, and these hooks are supported by bars, the ends of which are seen in fig. 107. The bars are supported by a frame, which is alternately raised or lowered by a lever attached to and acting with the treadle. If all these bars were raised at once, all the warp threads would be elevated; but if by any means some of the hooks were pushed off the bars, while the others were allowed to remain on, the warp threads in connexion with the latter would only be raised. Now the hooks are disengaged from the bars by means of horizontal wires or needles, one of which is shown separately in fig. 110: each wire has a loop or eye in the centre, through which the vertical lifting wires, fig. 107, pass. The horizontal needles are kept in place by means of spiral springs, contained in a frame, fig. 107, and the points of the needles project on the opposite side of this frame. Now it is evident that if a slight pressure were applied to any of the points, the needles would be driven into the frame. The vertical wires would be disengaged from the bars, and the warp threads in connexion with them would not be raised. On the removal of this pressure, the elasticity of the springs would drive the needles forward and restore the hooks to the bars.

The method of driving the needles back at the proper time so as to raise the different portions of the warp required to form the pattern, is by means of a revolving bar of wood (fig. 108), the sides of which are pierced with holes corresponding in numbers and position with the points of the needles. One of the sides of this bar is brought up against the points of the needles every time the treadle is depressed. If, however, this alone were done, the points would enter the holes, and no effect would be produced. But if some of the holes were stopped while others remained open, some of the needles would be driven back and others would remain undisturbed, and the warp threads in connexion with these latter would alone be raised. This is what is done in practice: each face of the revolving bar is covered with a card containing a smaller number of holes than those of the bar; so that when the points of the needles press against an unperforated part of the card, they are driven back, but when the points enter the holes of the cards, they enter also the holes of the drum, and the needles corresponding thereto remain unmoved. In this way the pattern is made out; the revolving bar presents a new card to the points of the needles at every quarter turn, supposing the bar to be four-sided. As the holes in the cards are arranged so as to raise in succession those healds which will make out the intended pattern, it is evidently necessary to have as many cards as there are threads of weft in the pattern. All the cards are tied together by the edges, so as to form a kind of endless chain, one complete revolution of which makes out the pattern; and by repeating it, the pattern may be repeated on the warp.

The preparation of these cards requires care. The pattern is drawn upon squared paper: that is, the order in which the threads are grouped is marked upon a *pattern paper* or *design*, as it is called, so divided by lines into squares as to represent a woven fabric on a large scale, the threads which make out the pattern being put in in appropriate colours. The pattern is next repeated in a frame containing a number of vertical threads, corresponding with the warp, when the workman with a long needle takes up such threads as are intersected by the pattern, inserts a cross-thread under them, and carries it over all the remaining threads in the same line, and he repeats this process until he has inserted a sufficient number of weft-threads to make out the pattern. The threads thus interlaced are attached to a card-punching machine. This acts on a principle identical with that of the Jacquard apparatus itself. It is furnished with lifting cords, wires, and needles, connected in the manner explained for fig. 107, so that on pulling the lifting cords the needles are protruded. In front of these needles, and answering to the revolving-bar, fig. 108, is a thick perforated iron or steel plate, each of the perforations of which contains a movable steel punch or cutter; so that on causing any of the needles to protrude they will drive before them their corresponding punches, and deposit them in a second iron plate, similarly perforated, placed against the face of the former one. Now, the method of protruding the steel punches required for each card is as follows:—One end of each warp thread in the pattern frame is connected in succession with the individual lifting cords of the machine: each thread of the weft is then taken by the two ends and drawn upwards, by which means all the warp threads passed under by this weft thread will be raised, and can be collected together in the hand: on pulling them, the particular lifting cords to which they are attached will cause the needles to protrude; these will drive out the cylindrical cutters which occupy the perforations of the fixed plate into the corresponding cavities of the movable plate. A blank card-slip is placed against the latter, which is taken to a press, where the punches are driven through the slip (fig. 109). The process being repeated for the other cards required to make up the pattern, the various cards are numbered and attached together in their proper order. The number of cards may vary from a few hundred to many thousand. The cards are arranged in folds, and partly supported upon a curved board over the loom, as shown in fig. 114.

Before the loom can be set to work, a number of preparatory steps have to be taken, which could not well be explained until the nature of weaving and the structure of the loom were understood. The preparation of the warp involves many details which may be included under the general term of *warping*, whereby all the warp threads are arranged alongside of each other in one parallel plane. That this is an operation requiring much care will be evident from the fact that in a width of twenty inches, as in silk goods, there may be eight or ten thousand threads, every one of which must occupy its proper place without entanglement or confusion. One of the oldest methods of warping was to draw out the threads in an open field, as is still done in India and China. Our uncertain climate and superior mechanical skill do not countenance so primitive a proceeding. An old arrangement, which we have borrowed from the woollen manufacture, is represented in fig. 115. This *warping frame* consists of two uprights, with a number of projecting pins for receiving the yarns, while the bobbins containing them are mounted in a frame. The warper ties all the ends of the threads together, attaches them to one of the pins, and, collecting them in one hand, walks to the other end of the frame, passes them over a

pin, and so on backwards and forwards until the desired length has been collected. Another method, represented in fig. 116, is the *warping mill*, consisting of a large reel, mounted on a vertical axis, to which motion is given by means of an endless band, which connects the bottom of the axis with a wheel turned by the warper. The bobbins of the yarn are mounted on skewers in a frame on the right, called a *travers*. The yarns from the bobbins are made to pass through a *heck*, fig. 117, also called a *jack* or *heck-box*. As the reel, fig. 116, revolves, the heck slides up and down between a couple of posts, whereby the warp yarns are wound spirally and smoothly over the sides of the reel. The use of the heck is to form the *lease*, that is, to divide the warp into two alternate sets, one for each heald, for which purpose the heck-block contains a number of steel pins, with a round hole or eye in the upper part of each, through each of which a yarn is passed. The pins are placed in alternate order in two frames, either of which may be raised at pleasure. The warper preserves the lease or crossing of the threads by tying through them at the top, just below the knot which fastens the ends of the yarn together, and before the warp is removed from the mill the yarns are tied together at the ends. The warp is made up into a bundle for the next operation, which may vary according to circumstances. Supposing it does not require to be strengthened by the application of size, it may be wound upon the yarn beam of the loom. The operation is called *beaming*, and is represented in fig. 118. The beam turns upon iron pivots, and is set in motion by being put into gear with a revolving shaft overhead; and the workman, holding in his hand a sort of comb, called a *separator*, or *rabble*, through the cane teeth of which the warp threads are passed, thus spreads the warp smoothly and evenly upon the beam.

As the warp is subject to considerable tension and friction during the process of weaving, it is usual to give it a dressing of glue, size, or paste, in order to strengthen it. This may be done, as in fig. 119, by passing portions of the warp through a hole in a trough, under a couple of rollers in the bottom of the trough, and then out at another hole in the side, which squeezes out the superfluous fluid, and so backwards and forwards several times. In the worsted manufacture, the yarns require to be *scoured*, to get rid of the oil used in the combing. They are immersed in a tub of soap-suds, as in fig. 120, passed between pressing rollers, and then *linked* or plaited, to prevent the warp threads from becoming entangled. Dressing and sizing are sometimes performed after the beaming, for which purpose the beams are mounted in frames, as in fig. 121; and the threads, being passed through reeds to keep them distinct, are sent between a couple of rollers covered with felt, one of which dips into a trough of paste. Cylindrical brushes rub the size into the fibres, and distribute it over their surface. The yarn is then dried by being moved over a chest filled with steam, and is finally wound upon the main yarn-beam. The yarns are also sized by means of the *sizing machine*, fig. 122, which consists of an iron trough surrounded by a case filled with steam, and called a *steam-jacket*. The trough also contains a number of rollers, over which the warp travels up and down, so as to keep the yarns longer in the warm fluid size, and, having passed out of the trough, the superfluous moisture is squeezed out by means of two large wooden rollers, after which the warp is dried by being passed over the cylinders of a *drying machine*.

The warp having been wound on the warp-beam, the next process is *drawing-in*, or passing every yarn through its proper eye or loop in the healds. For this purpose the yarn-beam is suspended by its ends, as shown in fig. 123, and the healds are also hung up near the free hanging ends of the warp yarns. The weaver and his assistant are seated one on one side and the other on the other side of the healds, and the assistant picks up each thread in its order, as determined by the lease rods, and presents it so that the weaver can easily draw it through the open eyes of the healds. The warp is then passed through the splits of the reed, portions of the warp being tied into knots as the drawing-in is completed, and these knots are connected with a shaft which is attached to the cloth-beam of the loom. The fineness of the cloth, or the *number* or *set of the reed*, depends on the number of dents of the reed in a given length, two threads passing through each dent. Thus a 60 *reed cloth* contains sixty warp threads in an inch. This simple method, however, is not followed at all places.

VI.—FINISHING PROCESSES.

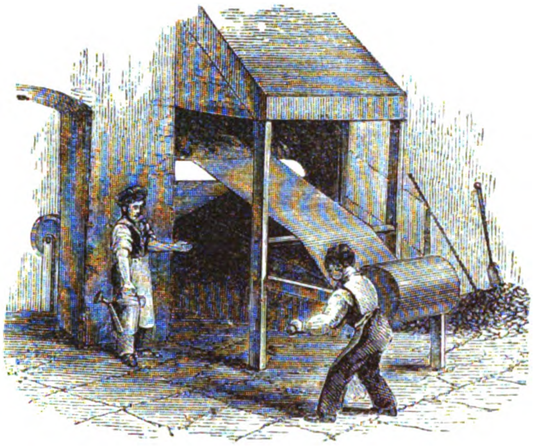
WOOLLEN CLOTH.

When the weaver has done his part, and the fabric is removed from the loom, it is seldom fit for use (except in the case of silk goods), but has to undergo a number of finishing processes, such as *fulling*, *teazling*, *shearing*, *singeing*, *bleaching*, *dyeing*, *printing*, *calendering*, *starching*, *making up*, &c. We shall have to notice all these processes; but we will first describe those which are peculiar to woollen cloth.

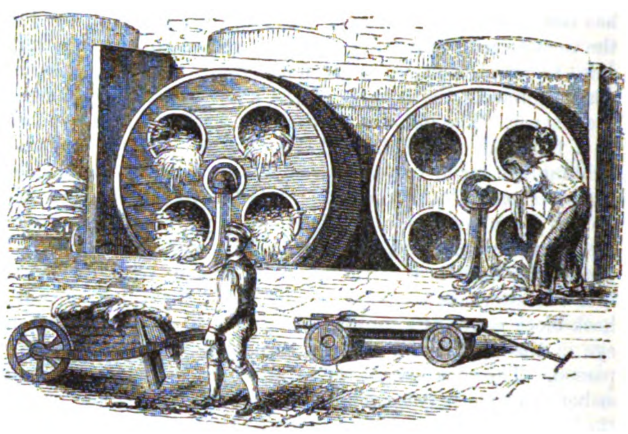
Broad cloth is woven in looms of large size, the width of the cloth being upwards of twelve quarters, in order to allow for the shrinking which takes place in the finishing processes. The edges of the cloth are finished with a narrow border of list, made of goat's-hair, or of coarse yarn, for the purpose of receiving the tentering-hooks, when stretched out to dry.

The first finishing process for woollen cloth is *scouring*, in order to get rid of the oil used in spinning, and of the size in dressing the warp. Scouring consists in constantly agitating the cloth in water containing some detergent substance, such as *Fuller's earth*, the alumina of which forms a soap with the grease, and is thus rendered soluble, and capable of being removed by washing. The *fuller's stocks*, next to be described, are also used with a quantity of soap and warm water, after which the cloth is passed through a *scouring machine*, fig. 124, and washed in hot water with the assistance of squeezing rollers.

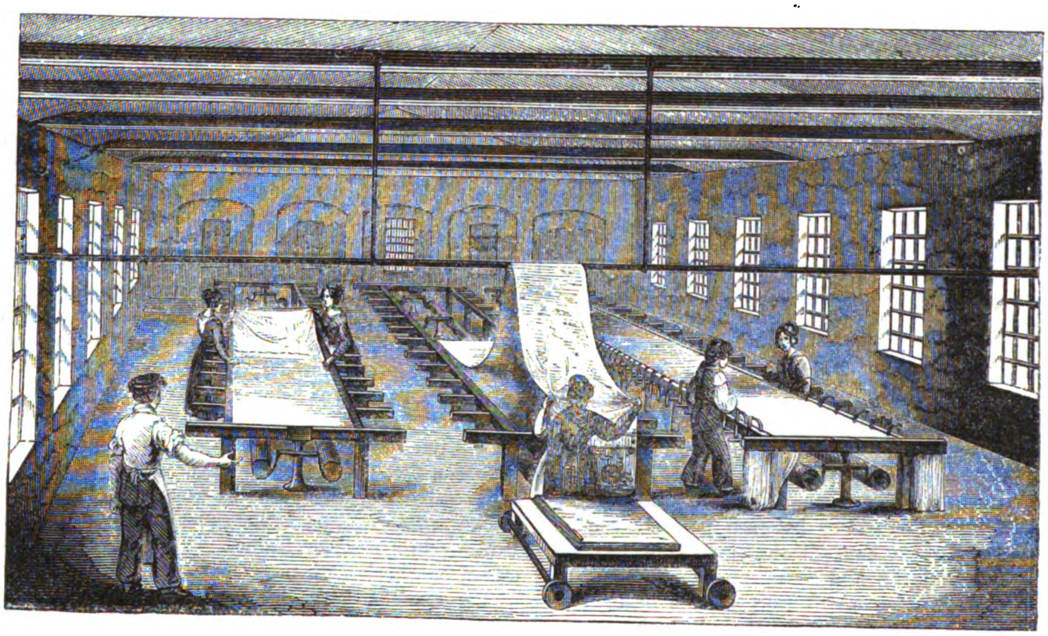
The *fulling mill*, fig. 128, consists of ponderous oaken mallets working in a *stock* or frame. The mallets are worked by *tapit wheels*, or wheels with projecting cogs, which bear on the shanks of the mallets, raise them to a certain height, and, suddenly releasing them, allow the heavy heads to fall by their own weight into an inclined trough, the end of which is curved. The cloth, being put into this trough, is exposed to the blows of the mallets, and by the form of the trough is turned round and round, so that every part may be acted on. At first the cloth is impregnated with soap, as already noticed. When this has been removed by washing, the cloth is returned to the fulling-mill, with fresh quantities of soap; where it is exposed for many hours to the action of the mallets, the object being now not to clean or scour, but to *felt*; that is, to produce such a motion among the fibres of the wool that their minutely jagged surfaces may lock into each other, so that the individual threads become lost under the thick felled surface which is raised upon them. The fulling stocks differ from the scouring stocks in the form of the trough, the end of which is square instead of inclined; so that the cloth receives the direct blows of the mallets, instead of being turned round and round. Indeed, it seems wonderful that the cloth is not pounded to a soapy pulp under the continuous blows of the ponderous mallets. An ordinary broad-cloth requires from sixty to sixty-five hours to full, and about eleven pounds of soap; it shrinks during the process from twelve quarters wide to seven, and from fifty-four yards in length to forty yards. Of late years the fulling-stocks have been superseded in great measure by the *fulling-machine*, where rollers do the work of the mallets, in a shorter time and with a less expenditure of soap.



131. SINGEING CALICO.

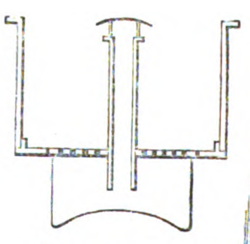


132. DASH-WHEELS.

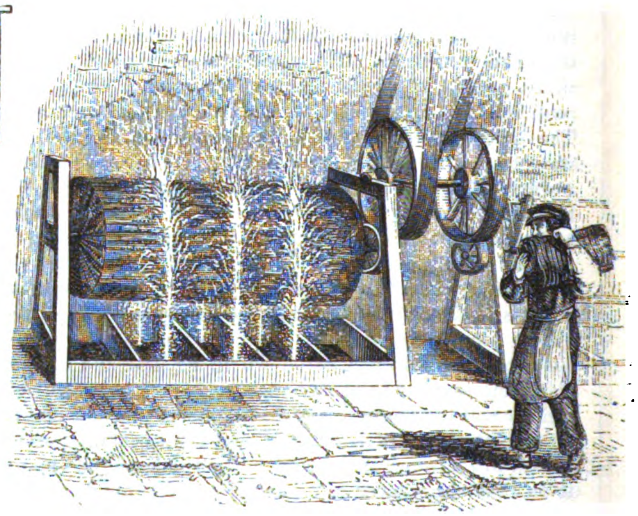


133. DRYING ROOM.—(*Muslins.*)

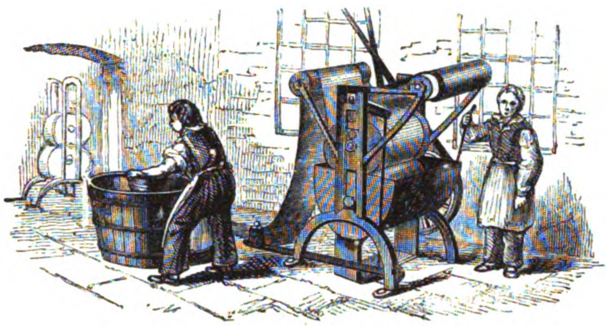
134. BOWKING KEIRS



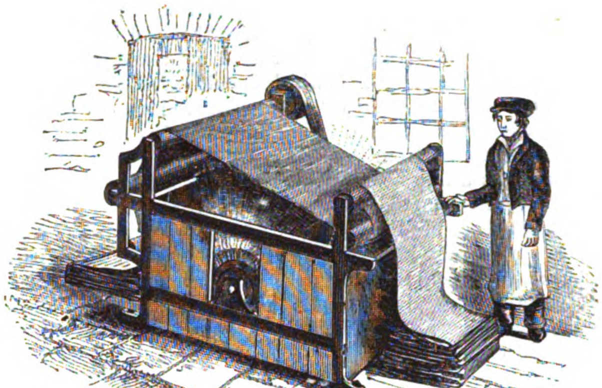
135. SECTION OF KEIR.



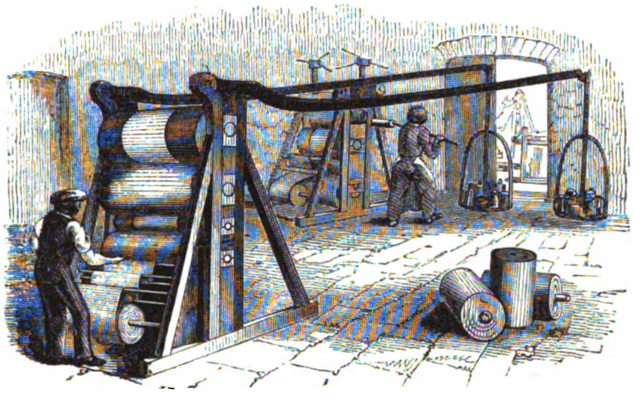
136. WASHING BY STEAM-POWER.



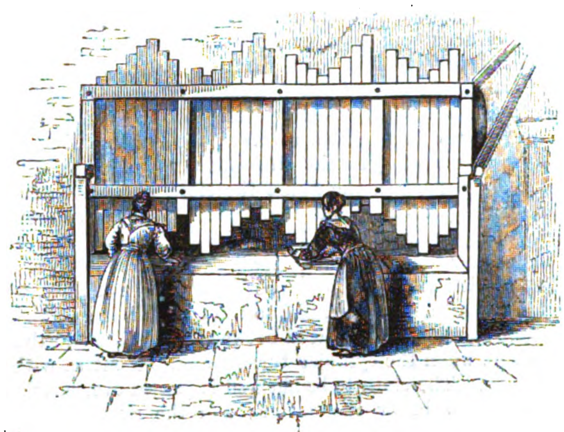
137. STARCHING MACHINE.



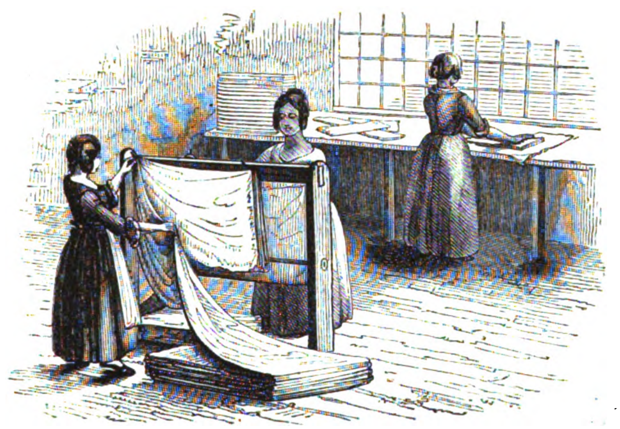
138. DAMPING MACHINE.



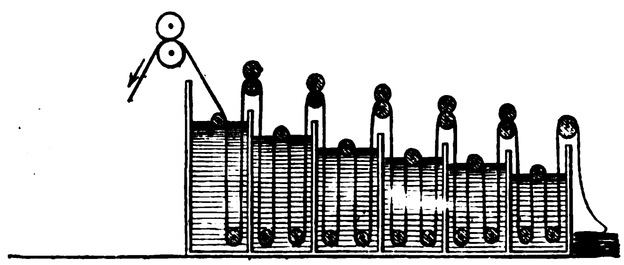
139 CALENDERING MACHINE.



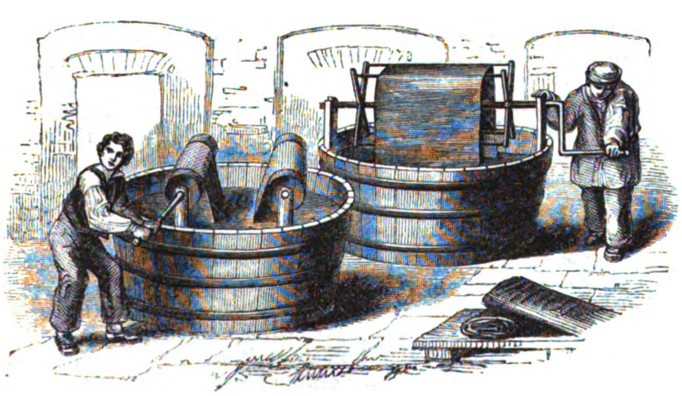
140. FLAT BEETLE.



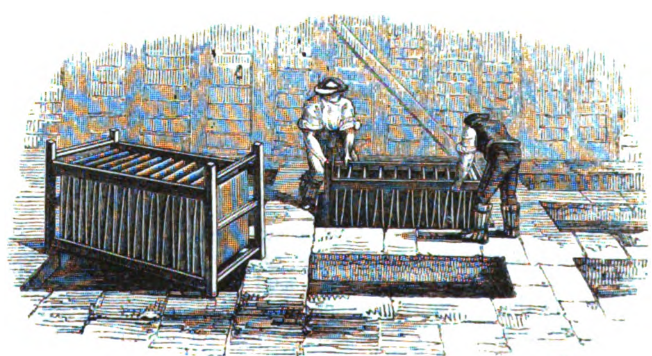
141. HOOKING FRAME.



142. RINSING MACHINE (*Vertical Section*)



143. DYE-BECKS.



144. DYEING IN INDIGO BLUE.

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After having been dried, the cloth is dressed at the *gig-mill*, fig. 126. It is first *roughed* or *rowed* for about twenty hours with teazles, the object being to raise the wool on the surface. The teazle is the prickly flower-head of a species of thistle (*Dipsacus fullonum*), fig. 125, which is cultivated for the purpose. As many as from 2,000 to 3,000 teazles are required for a piece of cloth forty yards long. Each head consists of a number of flowers, separated from each other by scales; and at the end of each scale is a fine hook, which is the efficient part in teazling cloth. When a number of these heads are mounted in a frame, and brushed against the cloth so as to comb up or raise up a nap on its surface, any kind of entanglement between these natural hooks and the cloth does not produce a rent or tear in the fabric, because the hook gives way. This effect is not easy to imitate artificially, however desirable it is to do so, since teazles form an uncertain crop and are costly. In the gig-mill the teazles are arranged in long frames attached to a hollow drum, and the cloth, guided by rollers, is moved in a direction contrary to that of the drum.

The fibres of the wool brought to the surface by teazling, being of unequal length, are next shorn, in order to make them level. For this purpose the arrangement shown in fig. 127 may be used, where there is a fixed semicircular rack, within which is a cutting edge or *ledger-blade*, and a large revolving wheel containing eight small cutting disks, which in contact with the ledger-blade form a number of cutting shears, each disk having a toothed pinion working into the semicircular rack; so that as the large wheel revolves, the cutting disks have an independent rotatory motion in addition to their revolution with the large wheel. In the figure the cloth is represented by the dark shaded portion. It is more usual, however, to employ the machine represented in fig. 129, which is called a *broad perpetual*, or in another form the *cutting machine*, which consists of an iron cylinder with cutting blades passing spirally round it, while in contact with them and parallel to the cylinder is a straight steel blade, so that anything placed between this blade and the cutter blade will, when the cylinder turns round, be cut as with a pair of scissors. The cloth to be sheared is passed over another steel blade directly below the cutter; and the raised fibres, being exposed to the action of the latter, are sheared off. For fine cloth the teazling and shearing are repeated.

The cloth is next arranged in regular folds with polished pressing boards between them, and subjected to the action of a hydrostatic press. Hot iron plates are sometimes used for the purpose, in order to give a satiny lustre and smoothness to the face; but as this is apt to become spotted by rain, it is exposed to hot water or to steam, which prevents the spotting. The cloth is also several times passed through a brushing machine, and is carefully examined, for the purpose of closing by hand any minute hole or break in the fabric, and also for touching with dye stuff any spot which may not be of the proper colour.

Halls for the sale of cloth are established in the Yorkshire districts. Fig. 130 represents the interior of the Coloured Cloth Hall at Leeds.

VII.—FINISHING PROCESSES.

BLEACHING, CALENDERING, DYEING, &c.

Calico, muslin, and other descriptions of cotton goods intended for sale in a white state, require to be bleached. The old method of doing this was to send the goods (chiefly brown linens) to the bleaching grounds of Holland, where, after some preparatory processes, they were spread out on the grass and sprinkled with pure water several times a day. In the course of several months' exposure to air, light, and moisture, they became bleached; and on being returned to this country, were distinguished by the name of *Holland*.

Many attempts were made to abridge this tedious process of bleaching; but none were very successful until about the year 1785, when it was discovered that one of the constituents of common table salt possessed the property of destroying vegetable colours. Common salt is a compound of chlorine and the metal sodium, and is called in chemical language *chloride of sodium*. When the chlorine is separated from the sodium, it assumes the gaseous form, and is of a yellowish green colour, whence its name, from the Greek word for *green*. The most convenient method of applying the chlorine for the purposes of bleaching is in combination with lime, forming the well-known bleaching powder, chloride of lime. A solution of this can be made with water, by which means the noxious qualities of the chlorine are avoided; this gas being, even when largely diluted with air, exceedingly irritating to the lungs, and in its more concentrated form producing suffocation.

There are several circumstances which interfere with the whiteness of cotton goods. The fibres of cotton are covered with a resinous substance, which prevents them from readily absorbing moisture; and also with a yellow colouring matter, which seems to be confined to the surface. This colouring matter is sometimes so small as to render bleaching unnecessary, were it not that during the spinning and the weaving the goods acquire certain impurities. The weavers' dressing has to be removed, together with quantities of rancid tallow or butter, used to soften the dressing when it has become rigid. There are also soapy and earthy matters, and the dirt of the hands, to be removed. When the goods are received at the bleach works, they are marked with the owner's name, with a needle and thread, or stamped with a wooden stamp, dipped in coal tar. Then comes the curious process of *singeing*, the object of which is similar to that already noticed for cotton yarn or thread, fig. 34; namely, to remove the fibrous down or nap from the surface of the goods, which would otherwise injure their appearance, and, in the case of coloured goods, prevent them from receiving the dye stuff properly. The singeing is a simple operation: a number of pieces of cloth are fastened together at the ends and wound upon a cylinder, the axis of which has a winch handle. The cloth is then drawn over a red-hot copper flue, as shown in fig. 131, which singes off the nap; after which it is conducted over a metal roller, which plays in a trough of water. The cotton is usually passed three times over the hot flue; twice on the *face*, or the side intended to be printed on, and once on the back. It is wound from one roller over the heated bar to another roller on the other side of the furnace; and there is a swing frame for lifting the cloth off the hot metal when required.

Each piece of cloth is next made up into an irregular bundle, and steeped in water for twelve or fourteen hours. It is then washed in a *dash wheel*, fig. 132, which consists of a cylindrical box revolving on an axis, containing four divisions with an opening in each, into which the pieces are put. A large quantity of water is admitted from behind, and the wheel is set in rapid motion; which gives to the pieces the amount of friction required for their washing. This removes much of the dirt and weavers' dressing, but not the grease. To get rid of this, it must be combined with an alkali, such as caustic soda; but lime, being cheap, is largely used for the purpose with boiling water, in a *bucking* or *bowking-keir*, fig. 134. It is also called a *puffer*. Its arrangement will be understood from the vertical section, fig. 135. It consists of two parts: an iron pan set in brickwork, with a fire underneath, and a cast-iron vat, for containing the goods, separated from the pan by a grating. In the centre is an iron pipe with a curved cover. The liquor in the pan, from the pressure of the cloth above it, cannot escape into the vat, except by passing up the central pipe; and as the steam accumulates, it forces up a quantity of hot alkaline liquor, which,

being reflected back by the curved cap, pours down upon the cloths, drenches them, and filters through them into the boiler, to be again raised and poured down as before. The boiling is continued for seven or eight hours.

The pieces are now clean; but the action of the lime has been to make them darker in colour than they were before. The lime is washed out at the dash wheel, or in a wheel shown in fig. 136, when they are fit for *chemicking*, as the treatment with the bleaching powder is called. The bleaching is conducted in stone vats, over each of which is a perforated trough; so that the liquor can be pumped up and rained down upon the goods. Care must be taken that the bleaching solution be not too strong, or it will make the goods run into holes. After about six hours, the cloth is of a light grey colour.

The next process is *souring*. The goods are steeped in a weak solution of sulphuric acid for four hours; the action of which is to decompose the chloride of lime, and by setting free the chlorine within the fibres of the cloth, to remove the colour. The acid also removes minute portions of oxide of iron; and the goods, when removed from the solution, are much improved in colour, though not sufficiently bleached. They are therefore boiled in a potash or soda *ley*, then washed at the dash wheels, again immersed in the bleaching solution, and after a thorough washing, become quite white.

This description applies to the bleaching of cotton shirting and the better descriptions of cotton fabrics which are to be printed on. The bleaching processes vary somewhat for different descriptions of cotton and linen goods. Wool is bleached by exposing it to the fumes of burning sulphur, or by steeping the goods in a solution of sulphurous acid.

After the cotton or linen goods leave the bleacher, they are passed to the calenderer; whose business it is to make the surfaces compact, level, and uniform, and otherwise improve their appearance. Each piece of cloth is drawn out to its full extent by being dragged through a cistern of water, on its way to a pair of rollers, and the edges are beaten out by knocking them against a smooth beating-stock. The pieces are then stitched end to end, and passed through a mangle, consisting of a number of rollers, and are next wound upon a roller to be starched. The starch is blued by the addition of a little indigo, and is often thickened with an equal bulk of porcelain clay, or equal parts clay and calcined plaster of Paris; the effect of which is to produce an apparently strong and thick cloth, an artifice which cannot be referred to without a word of censure. The *starching-machine*, fig. 137, consists of a trough for holding the starch, and a couple of rollers pressed together by levers; between which the cloth passes after dipping into the trough, and the superfluous starch is thus pressed out. After this the goods are dried upon cylinders made hot by being filled with steam; or the more delicate fabrics, such as muslins, are stretched between long frames, as in fig. 133, and dried in a room heated to about 100° by steam pipes. To prevent the muslin from becoming rigid during the drying, the two long sides of each frame are made to work backwards and forwards through a small space in opposite directions, lengthwise.

Many kinds of cotton goods require *glazing* or *calendering*, properly so called. The goods are damped by being passed over a revolving brush which raises the water in a fine spray, fig. 138, and are then passed between rollers, which are pressed together by means of long levers, weighted at the further end, fig. 139. When the rollers are smooth, the threads of the fabric are flattened, and a soft silky lustre is given to the surface. When two surfaces are passed between the rolls at the same time, the threads make an impression upon each other, and a kind of wiry appearance is given to the surface. The rollers are of various materials, such as iron, wood, paper, and calico, and require very nice workmanship in their preparation. Some of the rollers are of copper, engraved with a variety of figures and patterns, by which figured velvets are produced. The *water-surface* is produced by variously engraved or indented rollers. Variety is also obtained by heating one of the rollers by means of a red-hot iron placed in it. The surface of some goods, such as jacconets, Irish linens, &c. is modified by means of wooden stampers working on a stone surface, fig. 140. They are raised up by the projecting cogs of a roller, and are then allowed to fall by their own weight.

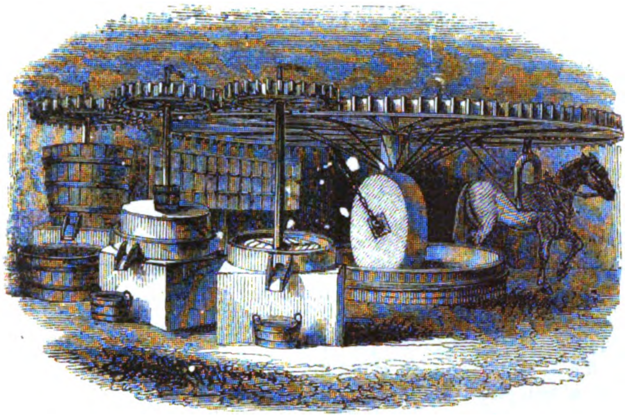
In making up the goods, they have frequently to be measured, an operation which is performed in the very act of folding, by means of the *hooking-frame*, fig. 141, which is a graduated iron bar, supported in a frame of wood, with a sharp projecting needle at one end, and a second needle attached to a piece which slides along the bar and can be fixed at any required distance from the first needle. The girl hangs the cloth upon the hooks in regular folds, until sufficient is collected for a piece, when it is removed from the frame for the purpose of making up.

Making up is a complicated affair, there being at least a hundred different modes of arranging the piece, according to the market for which it is intended; and also according to the particular country or district whose manufacture has been imitated. Thus there is the *falling-lap*, the *Wigan way*, the *cloth way*, the *Preston way*, and so on. Muslin is made up in *book-folds*, with yellow paper under the first fold to show the pattern, with the corners secured with variegated silk thread. Then there are labels of various sizes and colours in all the languages of the East and of the West, with armorial bearings and devices in gold, bronze, &c. The origin of all this variety is that spirit of competition which leads an enterprising commercial nation to seek out the consumers of a rival. Thus France was once distinguished for the excellence of her muslins: when our manufacturers, by dint of skill and enterprise, succeeded in producing muslin equal to that of France, it was not easy to overcome the prejudices of customers in favour of the latter; so that the dishonest expedient was resorted to of making up after the French fashion, and attaching fac-similes of French labels.

After the making up, the goods are compressed by means of the hydrostatic press, and are then ready for the market.

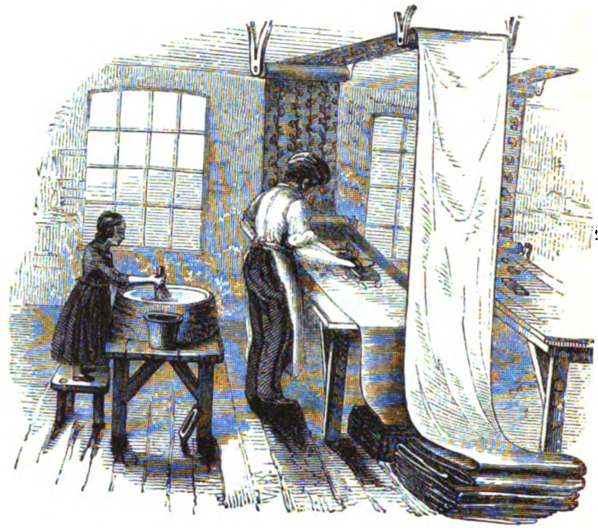
Colour is imparted to the bleached goods by the ancient art of *dyeing*, which depends for its success upon certain affinities or attractions between different bodies, which have been studied with so much success in modern chemistry. If, for example, a solution of chromate of potash be added to one of acetate of lead, the acetic acid of the latter will leave the lead to unite with the potash; while the chromic acid will combine with the lead, forming an insoluble precipitate of chromate of lead, or chrome yellow. If a piece of cotton cloth be impregnated with a solution of acetate of lead, and then be passed through a solution of chromate of potash, the precipitate of chrome yellow will be formed within the fibres of the cotton, and it will thus be permanently dyed. The infusions, solutions, &c. of dye stuffs, are made in vats (fig. 143), and the goods are passed many times through the liquor by one of the arrangements shown in the figure. As the goods require to be frequently rinsed, they are passed in and out of water many times by the arrangement shown in fig. 142. When the goods require to be dipped several times, and to be frequently exposed to the action of the air, they are ranged on frames, as in fig. 144, and let down into vats sunk in the floor, or are placed over their mouths to drain.

There is a method of dyeing with a *mordant*, which is usually a solution of a metallic salt, which has an affinity for the tissue as well as for the dye stuff. The latter consists of vegetable or animal colouring matters, which are soluble in water, but have not much affinity for the fabric. The mordant, of which common alum is an example, withdraws these colouring matters from solution, and forms with them upon the cloth itself certain compounds, which are insoluble in water. Some dye stuffs, such as indigo, which are not soluble in water, are rendered so by certain chemical actions; and the cloth being impregnated with the solution, is exposed to the action of the air, which restores the original colour of the dye.

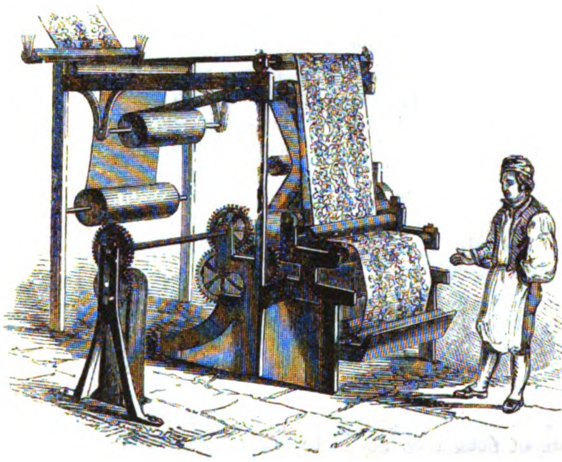


145. COLOUR GRINDING.

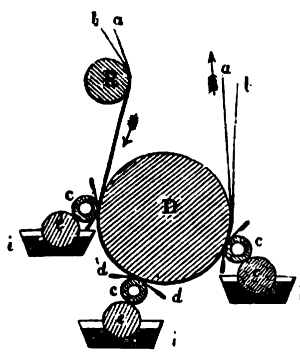
146. PRINTING BLOCK.



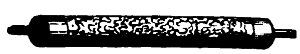
147. BLOCK PRINTING.



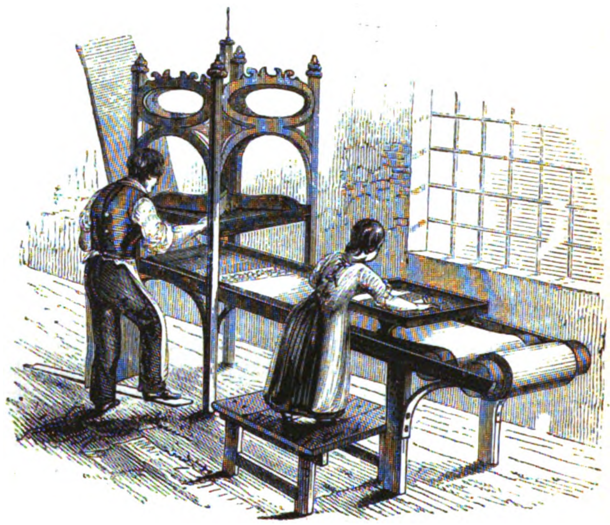
148. CYLINDER PRINTING.



149. WORKING PARTS OF CYLINDER MACHINE.



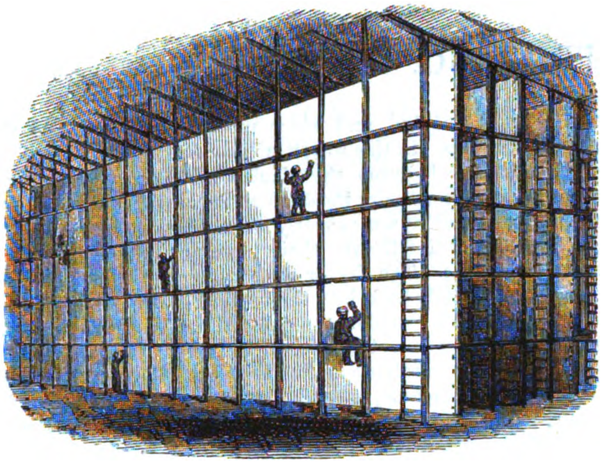
150. ENGRAVED CYLINDER.



151. PRESS PRINTING.

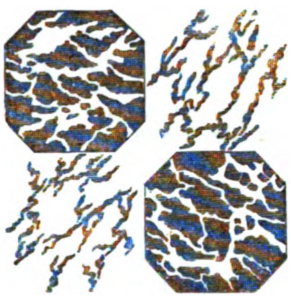
152. STEAMING

153 .BANDANA HANDKERCHIEF-PRESS.

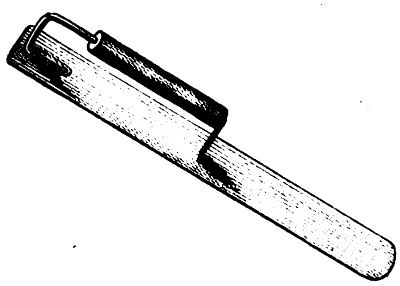


154. THE FRAME-ROOM

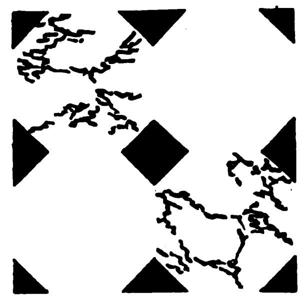
155. TROWEL COLOURING.



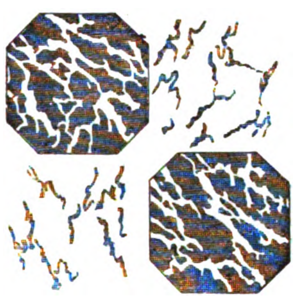
158. FIRST PORTION OF PATTERN.



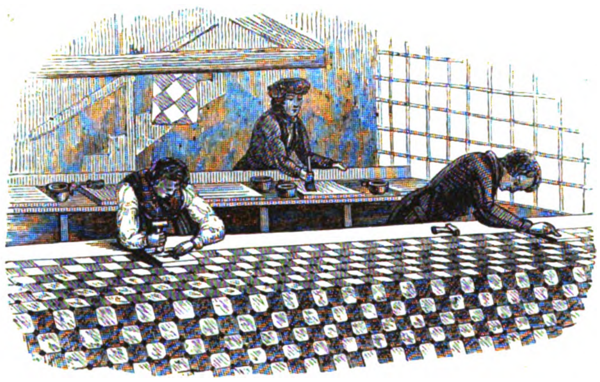
156. TROWEL.



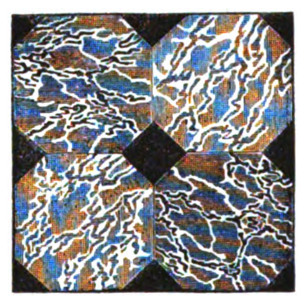
160. THIRD PORTION OF PATTERN.



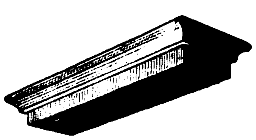
159. SECOND PORTION OF PATTERN.



157. PRINTING.

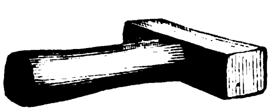


161. COMPLETE PATTERN.

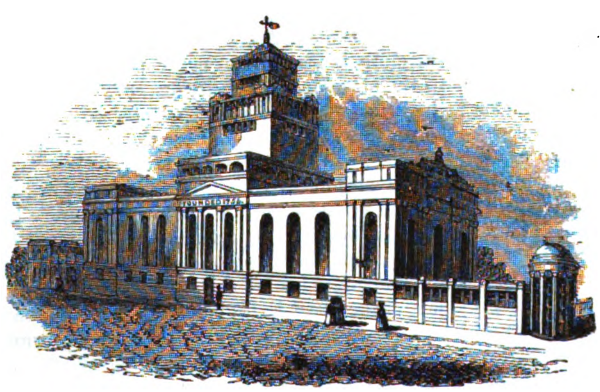


162. BRUSH.

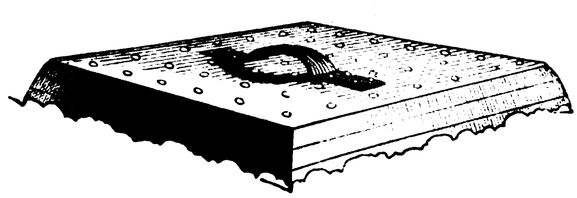
164. SCRAPER.



163. MALLET.



166. FLOOR-CLOTH FACTORY AT KNIGHTSBRIDGE.



165. PRINTING BLOCK.

VIII.—CALICO-PRINTING.

THE art of producing a coloured pattern on cloth is of ancient date; since the love of ornament is a natural propensity, and all that civilization does is to correct and refine it, and bring it within the principles of good taste. The town of *Calicut*, in the province of Malabar, originated our word *Calico*, and in that town the art of calico-printing was at one time carried on extensively. The large cotton-chintz counterpanes, called *Pallampoors*, are still occasionally met with, as specimens of Indian skill; the pattern being made out by impregnating certain portions of the fabric with wax, and then allowing certain dye-stuffs to act on the remaining portions. In Great Britain, the art of calico-printing has been one of successive improvement, both with respect to machinery and chemical applications; and also a constant struggle with the Excise to get rid of the duty on printed goods, which limited the consumption, and in many ways retarded the progress of improvement in the manufacture.

The simplest method of producing a pattern on calico (we speak of calico as a generic term, since linen, worsted, and mixed cloths are equally adapted to the process of printing) is by means of a wooden block, on the face of which the design is engraved in relief (fig. 146). The block varies from nine to twelve inches by from four to seven inches, and has a handle at the back. This block is charged with colour by pressing it upon a piece of woollen cloth, stretched tightly over a wooden drum, called the *sieve*, and floating in a tub of size, so as to form a kind of water-pad. A child called the *tearer* covers the sieve with colour, and keeps it uniformly distributed by means of a brush (fig. 147). The calico is printed at a long table, several pieces being joined end to end, and lapped round the roller, or arranged in folds, as in fig. 147. In order that the colour may dry, the cloth is passed over hanging rollers, so as to expose a large surface to the air. The printing-table is covered with a blanket; and the block being charged with colour, and applied to the calico, the impression is transferred by striking the back of the block with a wooden mallet. By repeated applications of the block to the sieve and to the calico, the surface of the latter is covered with a pattern in one colour. If the pattern be in several colours, there must be as many blocks as there are colours, and a distinct sieve for each colour. But when the design consists of straight parallel lines of different colours, they may be applied by one block at a single impression, by arranging the colours in small parallel tin troughs, and taking up a portion of each colour with a kind of wire brush, whence it is transferred to a peculiarly-arranged sieve, which supplies the block.

The greatest improvement in this art was the invention of *cylinder* or *roller printing;* which bears the same relation to block-printing as letter-press printing by steam does to the old hand-press. The cylinder machine will produce as much work in three or four minutes as can be accomplished by block-printing in six hours. The appearance of the cylinder machine will be understood by reference to fig. 148, while its working parts are represented in fig. 149. This machine is arranged for printing in three colours; *c* is a cylinder or roller (shown separately in fig. 150), mounted so as to revolve against two other cylinders, D, *e*; the cylinder *e* is covered with woollen cloth and dips into a trough, *i*, containing the thickened colouring matter. When the roller *e* revolves, it takes up a coating of colour, and distributes it over the cylinder, *c;* but as the colour is wanted only in the engraved parts of the cylinder, the excess of colour is scraped off the cylinder as it revolves by means of a sharp-edged knife, or steel edge, *d*, called *the doctor*. The large drum, D, is covered with an endless web of blanketing, *a*, which travels in the direction of the arrows, accompanied by the calico, *b*, *b*, which is to be printed, and which moves between it and the engraved cylinders. In this way, it will be seen, that as D revolves the calico travels between the blanket and the cylinders, and receives from each cylinder its share in the pattern in one colour; and if these cylinders are properly arranged, the different parts of the pattern will fall into their places and blend into one harmonious whole. The doctor is so arranged that the colour scraped off shall fall back into the trough, *i*. There are usually two doctors to each cylinder, one called the *colour doctor*, and the other, *d*, the *lint doctor;* the office of the latter being to remove the fibres which the roller acquires from the calico. The calico, as it leaves the machine, is conducted through a hot room, for the purpose of being dried. As many as eight colours may be printed at one operation. Of course, as the number of colours is increased, the difficulty of adjustment, so as to make each colour fall into its proper place, increases also.

Press-printing, fig. 151, is a refinement on ordinary block-printing. The block containing the pattern is, in this case, about 2½ feet square, and is so arranged in a frame, with its face downwards, that it can be raised and lowered at pleasure. The colour is supplied by means of a trough moving on wheels; so that it can be run under the block, which, being let down for its supply of colour, and again raised, the colour-trough is run out, and the block is brought down upon the calico. Striped patterns are produced in this way with much effect.

There are other mechanical modes of calico-printing; but the chemical arrangements are of a more complicated character. The preparation and application of the colours involve a large amount of scientific knowledge. Mordants are in constant use, and these and the colours must be mixed with proper *thickeners*, such as starch, gum, and other substances. A due exposure of the goods to the air after the printing, is called *ageing;* and this requires experience, as does also the proper method of removing the superfluous mordant and other colours, by washing in suitable solutions. In many cases, to produce fast colours, the printed goods require to be exposed to the action of steam; for which purpose they are rolled round a perforated cylinder, put under cover, as in fig. 152, and steam is blown through the cylinder. In some cases effects are produced by printing with a *resist paste*, the object of which is to prevent those portions of the cloth, covered with the resist, from acquiring colour when the calico is passed through the dye-beck. The paste being removed, we have the effect of a white design on a coloured ground; then again we have what is called the *discharge style*, where the goods being dyed are arranged in a hydrostatic press, as in fig. 153, covered with perforated metal plates; and strong pressure being applied, a solution of chloride of lime, or of some other substance which acts as a discharger, is allowed to percolate through, and the colour is removed immediately below the perforations. Then, there is the *padding style*, applicable to mineral colours; where the cloth is passed through a padding machine, which is similar to the starching machine, fig. 137, only the trough contains the thickened colour instead of starch. To produce a design in a mineral colouring matter, the cloth may be printed in one solution, and padded in the other.

The designs for calico-printing give constant employment to a class of artists known as *pattern designers*. In this branch of art there is abundant opportunity for the display of good taste, which is the more likely to be exercised and cultivated in proportion as the consumer of printed goods possesses it herself. Since the date of the Great Exhibition, our designers have greatly improved, and we are not now so dependent as we formerly were on French artists for our display of spring goods, which light up the windows of the linendraper.

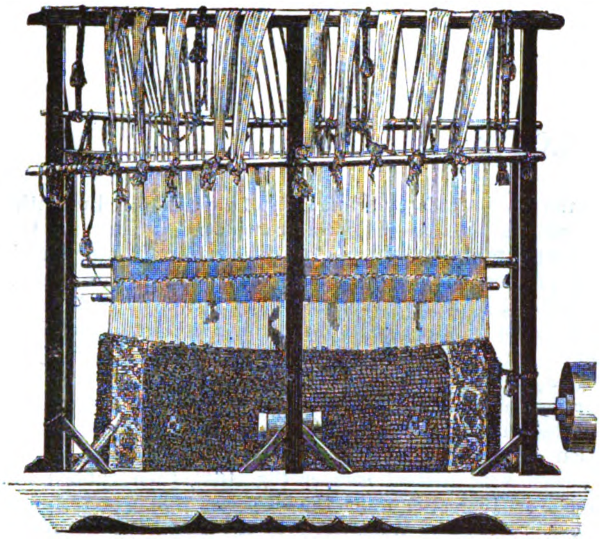
IX.—FLOOR-CLOTH.

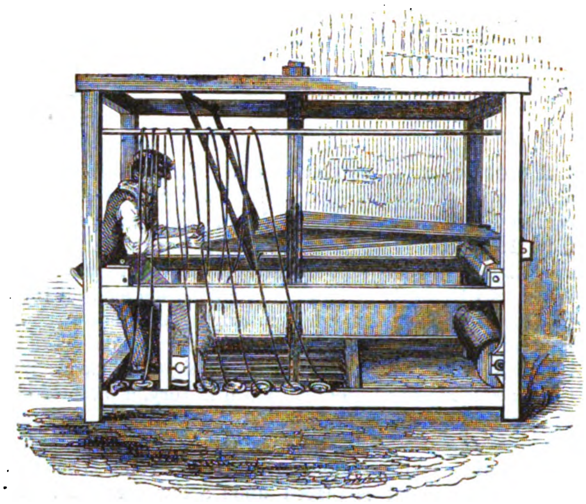
A FLOOR-CLOTH is a specimen of a rude kind of calico-printing, and may be appropriately described in this place. The cloth or canvas which forms the basis of floor-cloth is woven in widths of from 18 to 24 feet, so that there may be no seam. The looms are adapted to this great width, and the shuttle is thrown backwards and forwards by two men, one on each side the room. The warp is upwards of 100 yards in length, and the canvas is of the fineness expressed by sixteen or eighteen threads to the inch. It is manufactured at Dundee and the neighbourhood. When the bales are received at the floor-cloth factory, a piece of canvas of the required size is wound upon a wooden roller and removed to the *frame-room*, which contains a number of stout open frames, each furnished with scaffolding. Here the roller is set up on end, and the lower end is placed upon a low carriage and moved alongside the frame to which the canvas is attached by nailing the edge to an upright post, and to the top by means of hooks. The other upright edge of the canvas is similarly attached to another upright post, and it is made tight by screwing out the frame, whilst the top and bottom edge are secured to beams which can be turned round so as to tighten the canvas in a vertical direction. Each surface of the canvas may thus present an area of from 1,400 to 1,800 square feet. It is prepared for the reception of the paint by a coating of size, and by being well rubbed with pumice-stone, commencing from the top of the canvas, fig. 154. The paint is applied in dabs with a short thick brush, and is spread by means of an elastic steel trowel (fig. 156), about two feet long, and used with considerable force. When the paint has been spread, the man holds the trowel obliquely, so that its edge may lay bare the high threads of the canvas (fig. 155), while the channels between the threads become completely filled up. This first coat of paint, called the *trowel-colour*, is left to dry during ten or fourteen days; the surface is then sized and pumiced, and a second thinner coat is laid on with the trowel. This forms the back or under side of the floor-cloth. Three coats of trowel-colour are then laid on the face, and a fourth, or *brush-colour*, by means of a brush. This forms the ground of the pattern. The addition of the paint to the canvas has increased its weight four-fold: it is now cut away from the vertical posts, and also from the bottom, and is wound upon a roller from the bottom upwards, with the face inwards, and a quantity of paper is rolled up with it to prevent the surfaces of the coil from adhering. The roll is then hauled up into the printing-room. The pattern is impressed by means of blocks (fig. 165) of about 18 inches square, and 2½ inches thick, by a process almost identical with that already described for printing calico by hand, a separate block being required for each colour; the three blocks, figs. 158, 159, 160, being required to make out the complete pattern, fig. 161. The roller containing the floor-cloth which is to be printed is supported on its two extremities under the printing-table. A portion is unwound upon the table, the surface is slightly roughened with a steel scraper (fig. 164), then rubbed with a brush (fig. 162), after which the block (fig. 158) is pressed upon the colour-sieve and transferred to the cloth, the impression being made distinct by striking the back of the block with the handle of the mallet, fig. 163. After the first printer has proceeded a little way, a second printer with the block (fig. 159) goes over the same ground, while a third printer with a block (fig. 160) follows the second. Each printer has his own colour-sieve, and a boy serves as a tearer to all three. Fig. 157 represents the proceedings of all four workmen. As the printing proceeds, the finished portion is turned over the table to dry in the air, some months being required for the purpose.

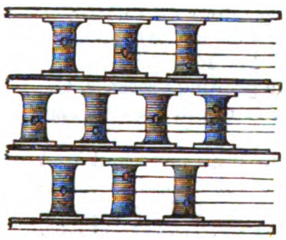
The grinding and preparation of colours is an important part of the business of the calico-printer, and of the floor-cloth manufacturer. Some of the coarser colours are crushed by means of the *edge-wheel*, shown in fig. 145; while others are ground with oil between mill-stones, as represented in the same engraving.

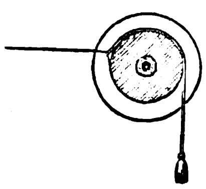
The patterns for floor-cloths should not be elaborate, but should rather follow the laws which regulate mosaics, marble pavements, and inlays for floors. What are called *all-over* patterns, of simple geometrical diapers in quiet, graduated tints, have the best effect; but where the work is large, frets and guilloches may be employed for borders, and a centre may be made out with geometrical combinations.

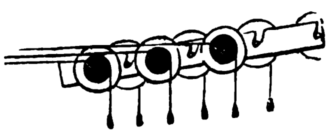
The buildings required in this manufacture are extensive, and some of them have pretensions of an architectural character, such as the factory of Messrs. Smith and Baber, represented at fig. 166.

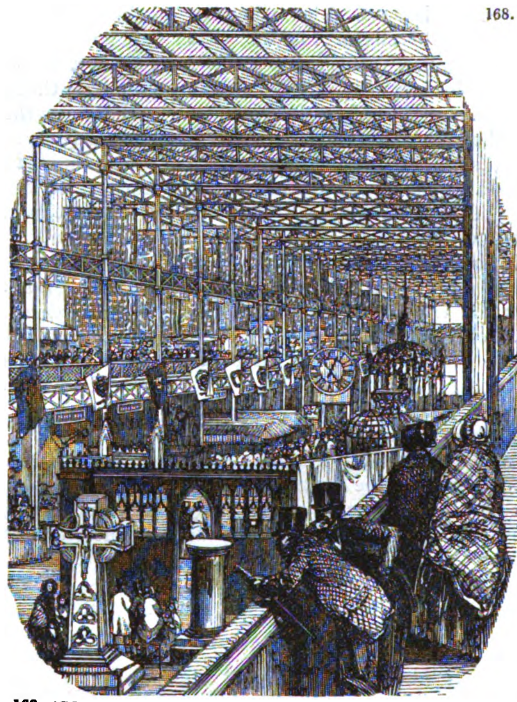

167. HINDOO CARPET LOOM.

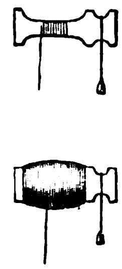

168. RUG LOOM.

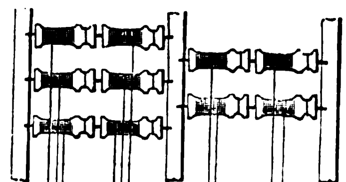

171. PORTION OF BOBBIN-FRAME.

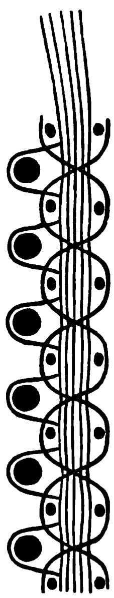

173. BOBBIN.

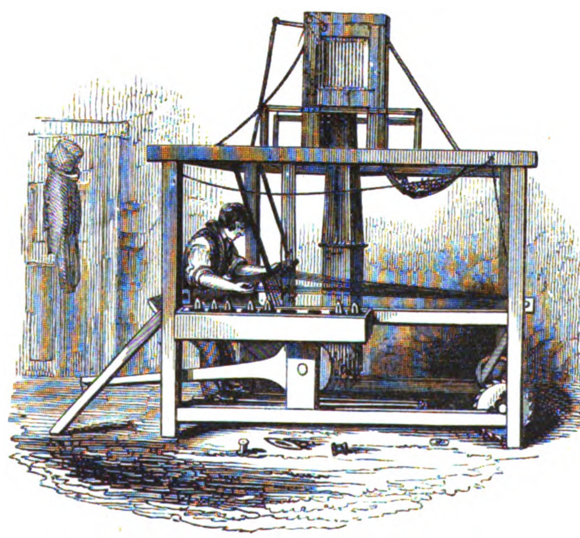

172. SIDE VIEW OF 171.

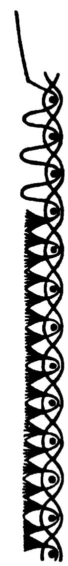

169. ARRANGEMENT OF CARPETS AT THE GREAT EXHIBITION.


174. BOBBINS.

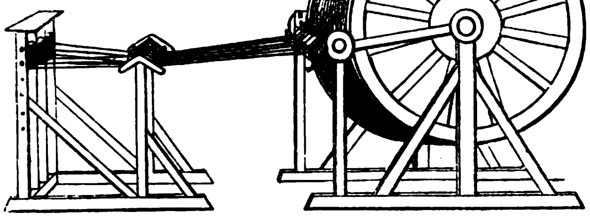

175. ARRANGEMENT OF BOBBINS.


176. STRUCTURE OF BRUSSELS CARPET.

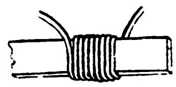

170. KIDDERMINSTER OR SCOTCH CARPET LOOM.


177. STRUCTURE OF WILTON CARPET.

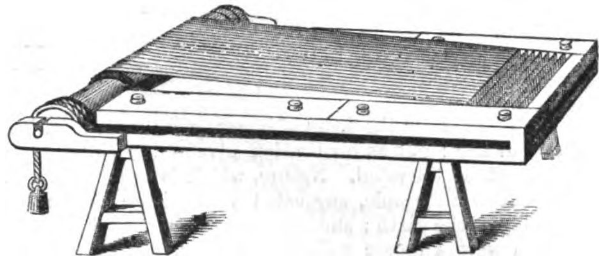

178. WIRES.



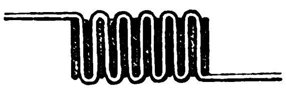
179. YARN-DRUM.



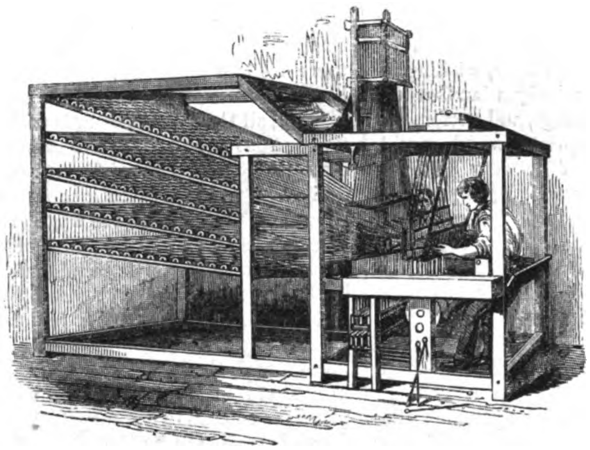
180. STRIP.



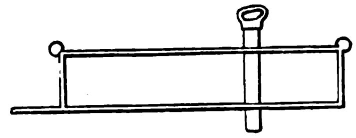
181 BEAM AND FRAME



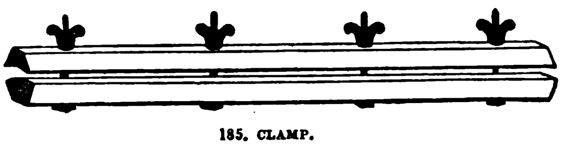
182. COILED-UP WARP



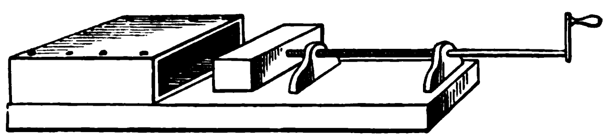
183. BRUSSELS CARPET LOOM.



184. KNIFE AND GUIDE.

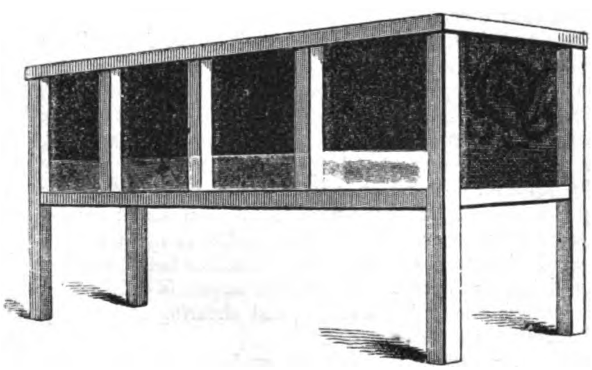


185. CLAMP.

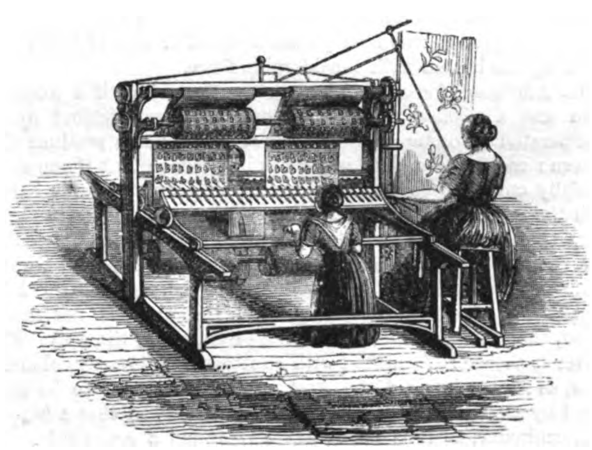


186. YARN CASE

187. EMBROIDERY NEEDLES.



188. WARP FRAME.



189. EMBROIDERING MACHINE.

X.—CARPETS.

In former times the floors of houses were covered with rushes, straw, or hay; but as civilization advanced, such rude materials could not be tolerated. Nature, which is beautiful in all ages, and among all people, suggested a substitute in the exquisite covering of the earth; and, accordingly, we find that the earliest carpets were a coarse web of one colour. As men acquired a taste for the beautiful, the flowers which adorn the turf suggested a method of ornamenting carpets. The patterns became more and more elaborate, until at length the whole contents of the flower-garden appeared to be concentrated on the floor of a single room. Had men continued to adorn carpets with such natural objects as occupy the ground, the art of ornamentation would have been properly exercised; but the artists of the floor, wishing to rival the artists of the wall, threw into their designs landscapes, buildings, architectural scrolls, reversed groinings, and perforated tracery, forgetting the broad principle of propriety, which would not represent on the floor objects which, if actually present, would be ridiculous and inconvenient. In carpets a *flat* mode of treatment ought to prevail. The colours ought to be quiet, and the pattern should not be so strongly marked as to mar the effect of the furniture, or of the wall decorations of the room. The display of carpets at the Great Exhibition of 1851 (fig. 169) was rather remarkable for excellence of workmanship than taste in design.

The earliest carpets were in the form of rugs. The Hindoo loom (fig. 167) represents the warp stretched in a vertical position, resembling in some respects the loom by which the Turkey carpet is produced. The Turkey loom consists of two upright pieces of wood, supporting a beam or roller at the top, upon which the warp or *chain* is wound, while another beam near the floor receives the carpet as it is made. The weaver, having thrown a weft thread once or twice across, fastens to every thread of the warp a small bunch of coloured worsted yarn, varying the colour according to a pattern before him. One row being completed, he passes a linen weft through the web and drives it well up, in order to hold the small bunches or tufts securely: another row of bunches is then added, and in this way a stout carpet is made in separate breadths, which, on being joined together, form one large carpet. Rugs are produced by a similar method, the warp or chain being laid horizontally, as in the common loom. Fig. 168 represents a rug-loom: the coloured worsted yarns are hung over a bar to the right of the weaver, who, taking the end of one of the bunches of yarn, attaches it to the chain, cuts it off at the proper length, then twists in another, which he severs in like manner, and so on until a row across the warp is completed, when he passes a shoot or two of weft, and drives up the batten with considerable force.

The *Kidderminster* or *Scotch* carpet is formed with a worsted chain and a woollen shoot. It consists of two distinct webs, incorporated into one another in such a way as to produce the pattern: each web or cloth is perfect in itself, so that if one were carefully cut away the other would be like a very coarse baize. Both these webs are woven at the same time, and each is brought up to the surface as the pattern may require in any particular part. A full colour is obtained by making the weft cross a warp of the same colour; thus, to produce a full red, red warp must be crossed by red weft; but in general the warp is not much varied, the variety of colouring being produced by the weft. The weaver is therefore furnished with shuttles of differently coloured wefts, as shown in fig. 170. Any particular colour can be concealed by sending the threads to the other web, so that a *two-ply* Kidderminster, as it is called, has a *right* and a *wrong* side. If, for example, the colours were green and red, the green portions on one side would be red on the other, and *vice versâ*. The apparatus for regulating the pattern is mounted on the top of he loom, and is worked by the method already described for the Jacquard apparatus (fig. 107).

The *Brussels* carpet has a linen web, which incloses worsted yarns of different colours, raised into loops as they are required to form the pattern. Fig. 176 gives the structure of Brussels carpet; the small black dots show the ends of the shoot, and the double waving lines two separate sets of linen warp or chain. Between the black dots, that is, between the upper and the under shoot, is the worsted yarn, usually consisting of five *ends*, all of different colours. But each end may consist of one, two, or three threads, according to the quality of the carpet. Supposing there are two threads to each end, there will thus be ten threads bound into the carpet every time the warp is shed. In forming the pattern, all that is necessary is to bring to the surface at any particular spot such of the five coloured yarns as are required, and by turning them over wires, represented by the large shaded dots in fig. 176, to form them into loops, which project permanently above the surface when the wires are withdrawn. As the coloured threads are taken up very unequally, they cannot be wound upon a beam, but have to be placed each upon a bobbin by itself. The bobbins are arranged in frames at the back of the loom, fig. 183, and each bobbin is furnished with a leaden weight, for the purpose of keeping the worsted slightly stretched. Portions of the frames, with the bobbins, weights, &c., are represented separately in figs. 171 to 175. There are as many frames in the loom as there are colours in the carpet, and the number of bobbins in each frame is regulated by the width of the carpet. The usual three-quarter width requires 260 bobbins to each frame, or 344 if the width be four-quarters. The ends are carried from each bobbin through small brass eyes, called *males* or *mails*, attached to fine cords, each cord being passed over a pulley fixed above the loom, and brought down again by the side of the loom and fastened to a stick. For a three-quarter carpet there are 300 males, cords, and pulleys. The pattern is made out by a Jacquard or some other arrangement; but it must be remembered that when the ends are raised, a round wire is placed in the shed, one of the treadles is then depressed, whereby one of the linen warps is raised, while the other warp, with all the remaining worsted ends, is depressed. The shuttle with a linen shoot is next thrown in, the weaver depresses the other treadle, by which means the worsted and the warp before depressed are now raised; and he then throws in a second or undershoot, striking each time with a heavy batten, so as to force the materials closely together and give solidity to the work. In this way a wire is woven in; and when a sufficient number of wires have thus been inserted, some of the earlier ones are pulled up by inserting a hook into a bow formed at the end of each wire.

The *Wilton* carpet differs from the Brussels in the form of the wire and the method of removing it from the loops. The wire has a groove in the upper surface, as in one of the forms shown in fig. 178; and instead of being drawn out, it is cut out by passing a small knife furnished with a guide, and called a *travat*, along the groove. The worsted loops thus cut form a pile or velvet, the structure of which will be seen in fig. 177. By increasing the dimensions of the wire, the Wilton carpet can be made of any thickness or quality. The quality is measured by the number of wires to the inch, the usual number being nine for Brussels, and ten for Wilton. The Wilton carpet is finished by passing it through a brushing machine, and shearing it level by means of a broad perpetual, fig. 129.

There are other varieties of carpet: such as the *Axminster*, which is similar to the Turkey; the *Venetian*, which is made for staircases and passages; the *Scotch*, which is identical with the

Kidderminster; and there is also the *Three-ply* or *Triple Ingrain* carpet, which resembles the Kidderminster, only it has three webs instead of two.

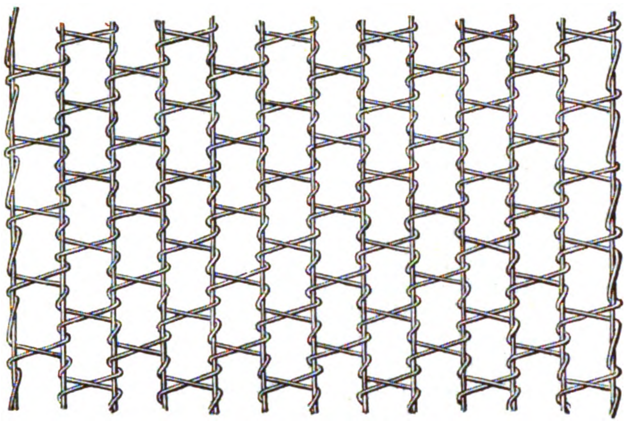
Several improvements have been introduced of late years into the carpet manufacture. We have seen that in the Brussels carpet five sets of coloured yarns are employed; while only one set can appear at the surface at any particular spot, the other four being concealed in the web. It occurred to Mr. Whytock that if, instead of four coloured yarns, he were to employ one yarn, dyed of the requisite colour at different places, he would be able to get rid of the complicated apparatus for producing the pattern; and the web could be made with only one body worked like a simple velvet. In such case the warp thread would have to be dyed by a special arrangement: this is represented in fig. 179, where the yarn is wound in regular coils round the circumference of a large drum, and the dye is applied by means of rollers working each in its own colour-trough, moving in a carriage; and being brought up to the drum, a coloured streak is communicated across it, in such a way that, on unwinding the yarn, a coloured mark is situated at equal distances along the length of the yarn. The cylinder is then turned round through a space equal to the breadth of the impression left by the colour-roller, and another streak of colour is applied; and in this way the cylinder is completely covered with colours which succeed each other according to the pattern. The yarns are then removed from the cylinder, the colours are fixed by steaming, and the yarns are wound upon bobbins; and when a sufficient number have been collected, they are arranged side by side, so as to form the warp. The arrangement of the colours on the cylinder, and side by side in the warp, is a simple matter of calculation, assisted by design or pattern papers. Before beginning to stamp the colours on the cylinder, a narrow black line is made across the yarns as a common starting-point; and, in arranging the warp, the yarns are held by means of a clamp, fig. 185, at this black line, which is advanced along the yarns as the pattern is repeated. The weaving is then conducted in the usual manner for plain weaving.

There is a method of making carpets, rugs, &c. without any weaving at all, but simply by cementing a nap or pile to plain cloth; for which purpose the yarns are warped upon a beam, fig. 181, which is supported at one end of a frame, and weighted with friction cords and weights, in order to keep the yarns properly stretched, the ends of which are attached to the front rail of the frame. The workman then takes a number of strips of metal, and places one under the warp, close to the front rail, and parallel therewith; inserting the ends into grooves made for the purpose in the sides. He then places a second strip edgeways, like the first, upon the upper surface of the warp, depressing the threads evenly between the two strips, and inserting the ends of the second strip into side grooves as before. The third strip is put under the warp, the fourth upon the warp; and in this way he proceeds until a quantity of warp is coiled up, as in fig. 182. The surface of this arrangement being combed or carded out, and pressed down evenly, a coat of fluid india-rubber or other cement is spread over it, and then some coarse cloth is applied so as to form a back to the carpet or rug. When this is dry, the frame may be turned over, and the several folds of yarn be cut, so as to liberate the metal strips; and in this way a beautifully soft nap or pile is produced.

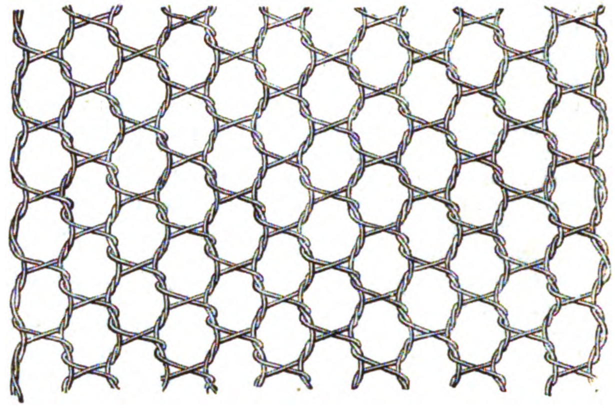
By a variation in the arrangements, ornamented carpets and rugs may be produced by this cementing process. A number of four-sided frames filled with canvas or perforated zinc are fixed upright in a convenient support, as in fig. 188. The person who works the design has the pattern on paper, or it may be sketched upon the canvas itself. Being furnished with as many yarns as there are colours or shades of colour, he begins by drawing with a needle a yarn through a hole or mesh in the canvas at one end, carrying it through the other frames and out at a corresponding hole in the last frame. By continuing this operation, all the holes at length become filled with their appropriate yarns. The mass of yarns thus collected is inclosed in a case open at both ends (fig. 186), and there is a solid ram or piston fitting into one end, for the purpose of forcing out portions of yarn as they are required. India-rubber or other cement being applied to the ends of the yarn, and this being covered with coarse cloth or canvas, a certain portion is cut off by means of the knife and guide, fig. 184; a fresh portion is pressed out of the case by means of the ram, and the process is repeated until the whole length of yarn is thus disposed of. When the two outer frames (fig. 188) have been five feet apart, as many as 480 copies of the same article have been produced.

A still simpler method of forming a napped surface is shown in fig. 180. The warp is wound round a thin strip of metal; and a number of strips, similarly covered, being packed side by side in a frame, some coarse fabric is cemented to the top, and the strips are afterwards cut out.

The figured cloths used for covering the walls of apartments, and included under the term *tapestry*, ought to include a style of decoration essentially distinct from that of carpets. Figures, landscapes, and ornamental devices may properly belong to tapestry, however much we object to the production of such forms in worsted or needlework. The word tapestry is from the French *tapis*, and this is from the Latin *tapetum*, which is identical with the Greek *tapes*, or *tapis*. The original meaning of the word was a covering for a bed, or a couch; and the French word, though generally applied to carpets, is also used to express other figured cloths used as coverings. Many of these figured cloths, in which the decorations were inserted by the needle, are now done by means of an embroidering machine, fig. 189. Such a contrivance is useful where the same ornament has to be repeated many times on the same fabric; and it enables a female to embroider a design with upwards of one hundred needles almost as easily as with one. The cloth is suspended in a vertical position, and the needles, furnished with the proper thread, and pointed at both ends, the eye being in the middle, as in fig. 187, are held by pincers in a frame, mounted in a carriage, which is wheeled up to the suspended cloth: this is pierced by all the needles, which on passing through, are seized on the other side by the pincers of a second frame. On drawing this away from the cloth, the needles will be drawn through it together with the threads; and on moving the second frame up to the cloth, the needles will pass through in an opposite direction, and be clipped and drawn through by the first frame. During these motions of the two frames backwards and forwards, the frame in which the cloth is suspended is moved in a regulated order, by means of a lever attached to a pantograph; so that by moving this lever over the points of an enlarged pattern, the point is slightly shifted at each motion, and the pattern is repeated thereon, on a small scale, by the passage of the needles.



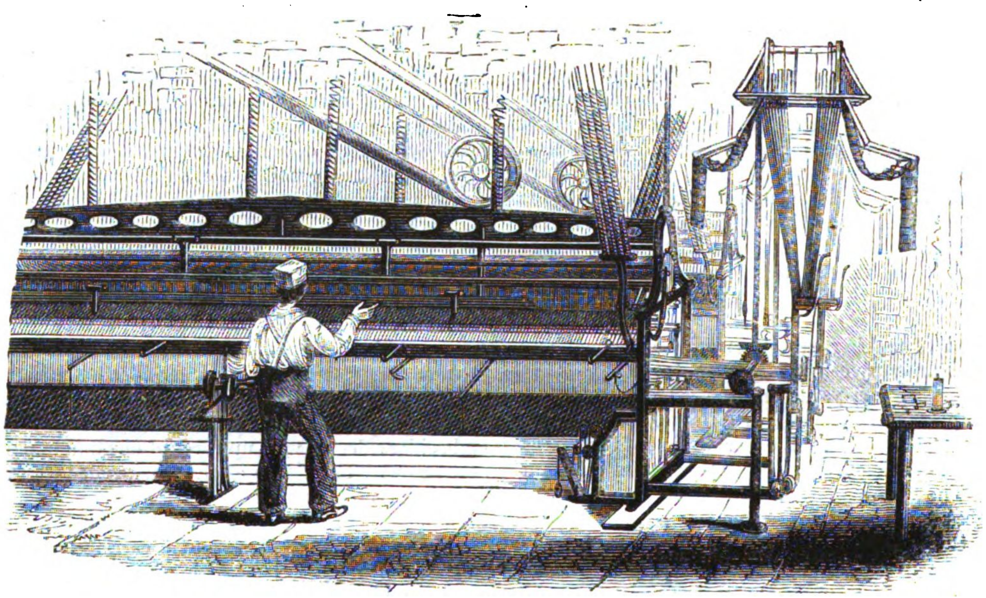
190. ILLUSTRATIONS OF LACE.



191. SPECIMEN OF LACE (*Magnified*).

192. PLAIN WEAVING.

193. TWILLED WEAVING.

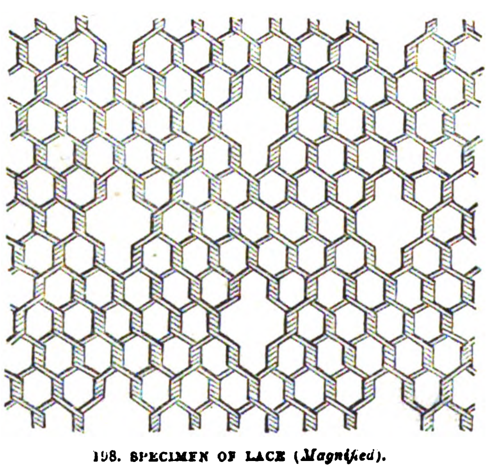


196. BOBBIN NET MACHINE.

194. STRUCTURE OF GAUZE.

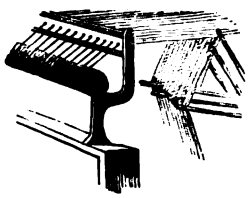
195. STRUCTURE OF LACE.

197. PILLOW LACE MAKING.

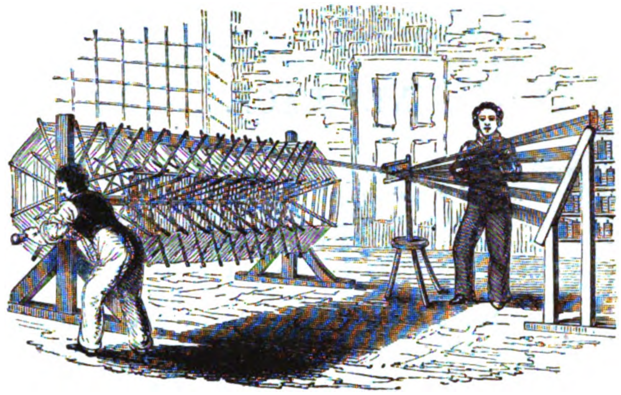


198. SPECIMEN OF LACE (*Magnified*).

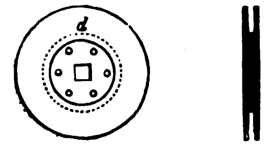
199. FILLING THE BOBBINS.



201. THREAD-BEAM.

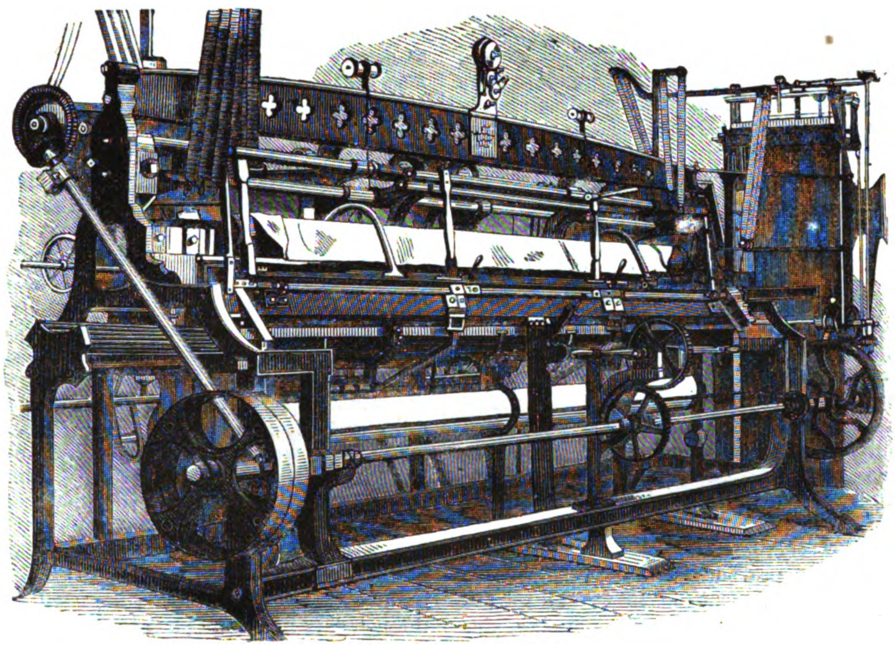


200. WARPING.

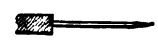


202. WEFT BOBBIN.

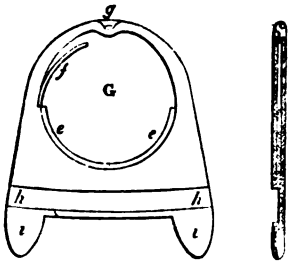
206. NEEDLE.



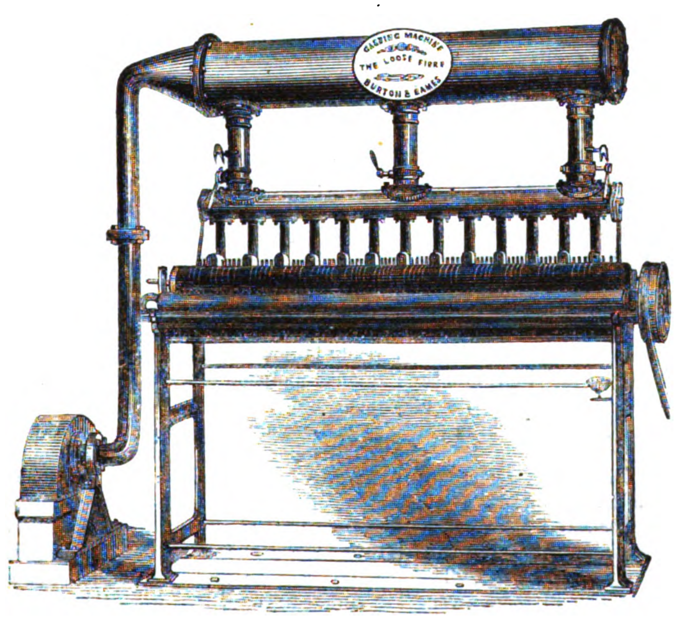
203. BOBBIN-N[illegible]ACHINE SHOWN AT THE GREAT EXHIBITION.



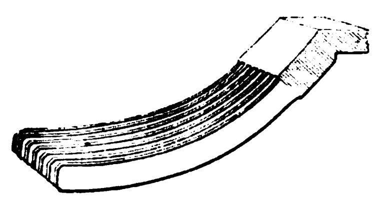
207. POINT.



205. BOBBIN CARRIAGE.



204. GASSING MACHINE.



2[illegible]. PORTION OF COMB

XI.—LACE.

The delicate fabric known as *lace* (a word said to be derived from the Latin *lacinia*, the guard-hem or fringe of a garment) was formerly made of such costly materials, and at so slow a rate, as to be one of the distinguishing articles in the dress of a wealthy or noble person. Nor was its use confined to the fair sex, as we see by the portraits, by Vandyke and other eminent artists, of the princes and nobles of the seventeenth century; and so much pains has the artist taken with this article of dress, that it is easy to name the variety thus faithfully copied. For example, in the pictures by Sir Peter Lely and Sir Godfrey Kneller, the *Brussels Point* is the favourite variety, in which the net-work is produced by bone bobbins on a pillow, while the pattern is afterwards worked in with a needle.

The difference between weaving and lace-making will be seen by reference to figs. 192 to 195. Fig. 192 represents *plain weaving*, and fig. 193 *twilled weaving*: forms which have been already explained. Fig. 194 represents the structure of *gauze*: in this, after every cast of the shuttle, the warp threads are made to cross each other, whereby the weft threads represented by the black dots are separated, and a firm but transparent texture is produced. In fig. 195, the threads of the weft are twisted round those of the warp, which twisting is the distinguishing feature of lace.

If we examine a piece of lace, it will be seen, that while a series of warp threads proceed in one direction, nearly parallel to each other, as in plain weaving, the weft threads are inserted differently. Each weft thread (fig. 190) twists once round each warp thread, until it reaches the outermost one, when it makes two turns; proceeding, after the second turn, towards the other border, in a reverse direction. By means of this double twist, and the return of the weft threads, the selvage is formed. The twisting and interlacing of the threads produce six-sided meshes, as in figs. 191, 198.

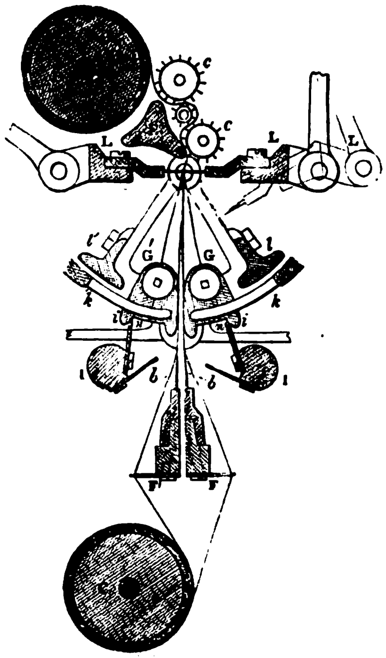
Pillow or *bobbin-lace*, the original manufacture, is made on a hard stuffed pillow or cushion, previously covered with the pattern drawn out on a piece of parchment (fig. 197). The threads are wound upon bobbins, and, in order to form the meshes, pins are stuck into the cushion, and the threads are twisted round them. The pattern on the parchment indicates where these pins are to be inserted, and also gives a design for the gimp or thicker thread, which is so interwoven within the meshes as to form flowers, curves, &c. The bobbins hang down by their threads on different sides of the cushion; and the lace-maker, with a pair in each hand, twists them in such a manner as to form the sides of the mesh. The lace made by hand is distinguished by such terms as *Honiton*, and *Thread* or *Pillow*-lace; there are also *British Point*, *Tambour*, and *Limerick* laces. Some descriptions of lace are made with pure handspun linen thread, worth from 100*l.* to 120*l.* sterling per lb. France is eminently a lace-making country; and the manufacture extends over a large part of that country; each district having its peculiar style, which is immediately recognised by good judges, although the mode of manufacture and the material may be the same in several districts. The seats of manufacture give names to the different varieties, such as *Point d'Alençon*, *Lisle*, &c. Belgium is also eminent for laces, which include the four great varieties of *Brussels*, *Mechlin*, *Valenciennes*, and *Grammont*, each of which has many varieties.

Where the chief cost of an article arises from the large amount of manual labour bestowed on its production, attempts would naturally be made to produce it at a cheaper rate by self-acting machinery; especially where the article is a beautiful object of dress, for that presents irresistible attractions to all classes. The origin and progress of lace-making machines would form a very curious chapter in the history of invention. In this, as in many other cases, will be found the usual opposition on the part of the workpeople to the introduction of machinery; there too may be noticed the usual kind of perseverance, privation, and distress on the part of the inventors, although in this department of the useful arts they are more numerous than in almost any other with which we are acquainted. There too will be found the usual failure of the many, and the marked success of the few. At one time, men were so bent on making meshes by machinery, that they could think and talk of nothing else; and, when sitting down to enjoy a little leisure, they would be seen, with serious face and knitted brow, moving strings about upon their fingers, and passing the combination from hand to hand as if they were playing at grown-up "cat's cradle." The production of a lace-making machine thus grew into a passion amounting even to monomania, and many men ended their lives in a lunatic asylum. This is a common story with inventors, who, often without a spark of mechanical genius, set themselves to work to solve problems which can only be fairly grappled with by the highest constructive skill aided by a knowledge of theoretical science; and even then the finished machine is often but the result of a long series of minor improvements grafted on to the first crude idea.

The lace-making machine is complicated; but we will endeavour to give a clear idea of the principle of one variety known as the *bobbin-net machine*, figs. 196 and 203. But first as to the preparatory processes. The thread is wound upon a roller for the warp, and upon bobbins for the weft. The warp threads are wound upon a reel, fig. 200, and thence transferred to a roller or *thread-beam*, which extends the whole length of the lace frame. The weft threads are wound upon small bobbins, seen in front and in section, fig. 202. Each bobbin consists of two thin brass disks, with a hollow in the middle of each, and riveted together so as to leave a circular groove between them for the thread. In the centre is a square hole, through which is passed a square spindle, to facilitate the winding. One or two hundred bobbins being thus spitted, the thread is passed from the drum, fig. 199, through slits in a brass plate to the bobbins; and, as the rod is turned round, the drum revolves and delivers its thread to the bobbins, while a hand, moving round a dial plate, shows how much thread has been delivered by the drum. Each bobbin is next inserted into a *bobbin-carriage*, seen in front and in side section, fig. 205. The bobbin is inserted in the space, G, the narrow edge, *e e*, fitting the grooved borders of the bobbin, while the spring, *f*, prevents the bobbin from falling out. The thread is conducted through the eye, *g*, at the top of the carriage, and on pulling this thread, the bobbin turns round.

These details being understood, we may describe the action of the bobbin-net machine by means of fig. 209, which shows the working parts. We have referred to this machine as being complicated. Now, complication in a machine may arise from the multiplication of similar parts, or from a large assemblage of different parts. Any one looking into the case of a church organ would pronounce that instrument to be very complicated, but it really is not so; the apparent complication arises from the frequent repetition of the same parts. A steam-engine, or a steam printing-press, on the contrary, is complicated, because in either case there are many different parts and many different motions to be followed out and understood. The bobbin-net machine involves both these conditions. The parts are numerous, and some of those parts are repeated many hundred times. In order, therefore, that the reader may follow out our description, we insert the principal illustrative diagram in the body of the text; and it will be understood that the motions described for two bobbin-carriages, two warp-threads, &c. apply equally to ten or

fifteen hundred repetitions of the same parts in the same machine. The warp-thread is wound upon the roller, C, while at the top of the frame a similar roller, D, receives the finished work. Between these two rollers the warp-threads are extended in vertical lines. F F are guide-bars, extending the whole length of the machine, with slits in their edges, through which the warp-threads are conducted in two rows, one on each side, to the eyes, *b b*, of



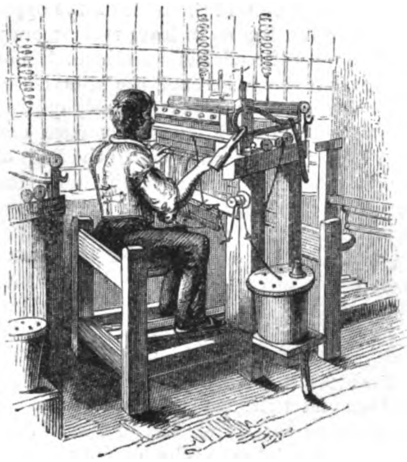
209. WORKING PARTS OF BOBBIN-NET MACHINE.

needles, one of which is shown separately in fig. 206. Each guide-bar, which contains a range of these needles equal to one-half the number of threads in the warp, is arranged so as to shift slightly to the right or to the left, to allow the bobbin-thread to pass to the right or to the left of the warp-threads as often as it is necessary to form the twist. The number of bobbins with their carriages is equal to the number of the weft-threads ; and as these have to pass through the narrow intervals of the warp-threads, they are arranged in a double line in two rows, G G, on each side of the warp-threads. The bobbins are supported between the teeth of a kind of comb, *k k* (a portion of which is shown separately in fig. 208), for which purpose the bobbin carriages have a groove, *h h*, fig. 205, corresponding to the interval between every two teeth of the comb. There is one comb on each side of the warp, and the free ends of the teeth in the opposite combs stand so near to each other as to leave room merely for the proper motions of the warp-threads between them. Hence the bobbin carriages, in passing across through the intervals of the warp, reach the back bolts before they have entirely quitted the front ones. The carriages are driven alternately from one comb to the other, by two bars, *l l;* and when one of the lines of carriages is pushed nearly across the intervals of the warp, the foremost of their projecting catches, *i i*, is engaged by a plate, *n*, attached to a shaft, I, which pushes it quite through. The beam which carries the combs can be shifted a little to the right or to the left, so as to change the relative position of the opposite combs by one interval or tooth, and thus to transfer the carriages to the next adjoining teeth. By this contrivance the bobbin carriages make a succession of side-steps, to the right in one comb and to the left in the other, in the course of which counter-march they cross each other and their threads twist round the vertical warp-threads, and thus form the meshes of the net. A *point-bar*, L, containing a row of pointed needles, one of which is shown separately, fig. 207, then falls with its points between the warp and weft threads, and carries up their interlacements, so as to form a new line of holes or meshes. The whole working of the machine thus becomes a constant repetition of twisting, crossing, and taking up the meshes on the point-bar.

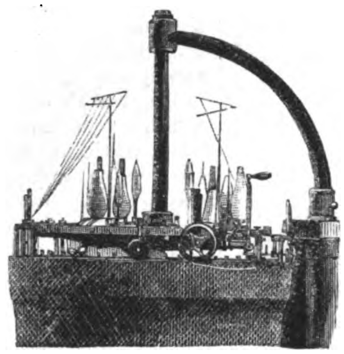
The beauty of bobbin-net lace depends on the quality of the threads, and the equal size and hexagonal shape of the meshes. The closer the warp-threads are together, the smaller are the meshes and the finer is the lace. The number of warp-threads in a width of one yard may vary from 700 to 1,200 ; the fineness of the lace, or the *gauge*, or *points* as it is called, depends on the number of slits or openings in the combs, and consequently on the number of bobbins in an inch of the double tier. A length of work counted vertically, containing 240 holes or meshes, is called a *rack*. Well-made lace has the meshes slightly elongated in the direction of the selvage. A piece of bobbin-net may be twenty, thirty, or more yards in length, and of variable breadth. The narrow quillings used for cap borders are worked in the same frame: many breadths at once are united by a set of threads, which are afterwards drawn out.

English machine-made net is chiefly confined to *point-net*, *warp-net*, and *bobbin-net*, so called from the peculiar construction of the machines by which they are produced.

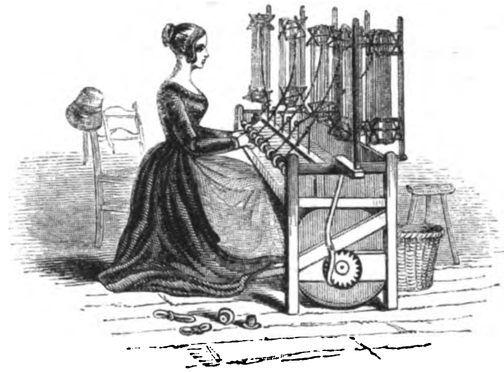
After the lace has been removed from the machine, it is *gassed* by being passed over a row of gas flames, supplied by the apparatus represented at fig. 204. The lace is then examined, defective meshes are mended by women, called *lace-menders*, who have a method of perfectly restoring the damaged meshes. It is then dressed, rolled, ticketed, and made up by processes similar to those already described for muslin.



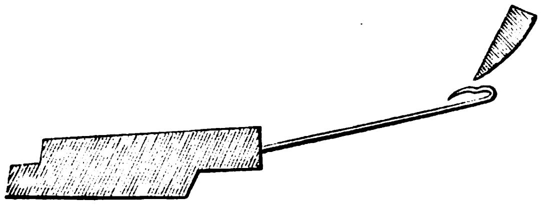
210. HOSIER AT WORK.



211. CIRCULAR LOOM.

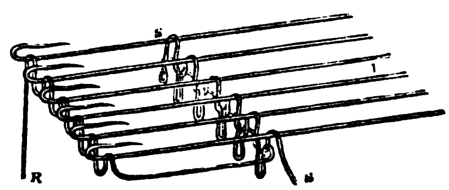


212. WINDING.

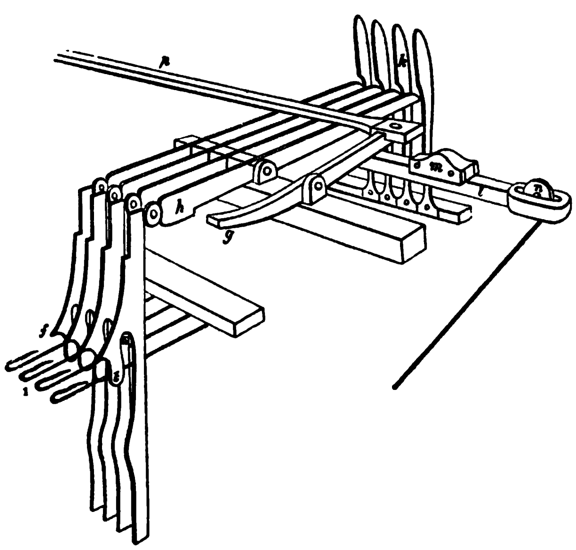


213. NEEDLE OF THE ACTUAL SIZE.

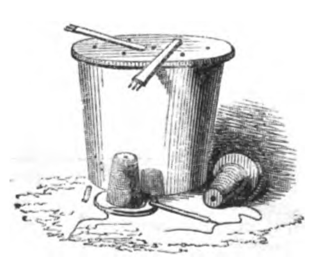
214. CAVITY.



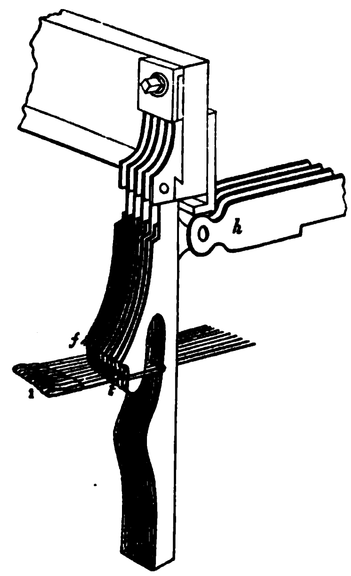
215. NEEDLES AND LOOPS



216. JACKS, SINKERS, AND SLUR

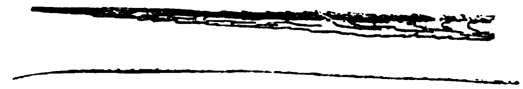


218. BARREL FOR BOBBINS.

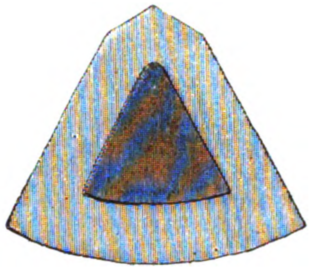


217 SINKERS.

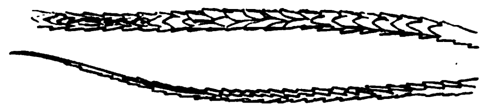
219. FILAMENT OF WOOL (*Magnifica*).



222. HARE'S FUR.



220. STRUCTURE OF NEUTRIA.



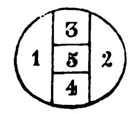
223. STRUCTURE OF RABBIT'S FUR.

221. STRUCTURE OF MUSQUASH.

228.

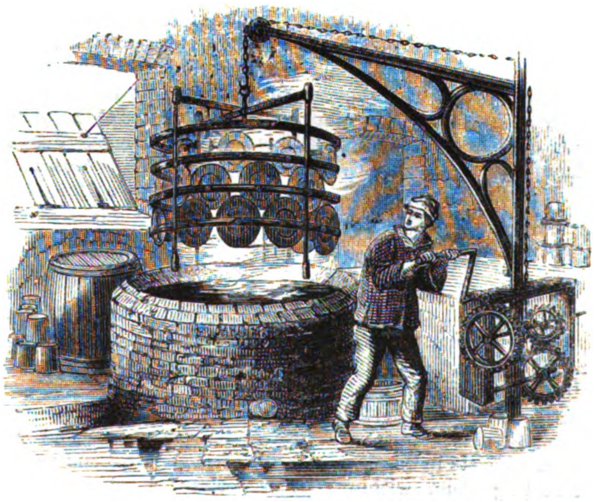
229.

224. BOWING BEAVER FUR.



230.

225. HAT BATTERY.



226. HAT-DYEING.

XII.—HOSIERY

The *Stocking-frame* is an ingenious contrivance for knitting by machinery instead of by hand. In *knitting*, a single thread is entwined so as to produce a fabric consisting of a succession of loops. In *netting*, a single thread is formed into meshes, produced by tying the thread or cord into hard knots at those points where it crosses upon itself. If the thread of a stocking be broken, a hole is produced, which continually enlarges by the unlooping of the thread; but one of the meshes of a net may be broken without injury to the rest.

The stocking-frame is a rare example of a capital invention, made in an age by no means distinguished for inventive skill in mechanics. The age which produced Shakspeare and Spenser, Bacon and Raleigh, distinguished as it was by the highest order of genius, did not understand the advantages of machinery in stimulating production; but on the contrary, regarded with suspicion whatever tended to abridge the labour of the hand. The answer of Queen Elizabeth to Lord Hunsdon, on being applied to for a patent for the stocking-frame, is characteristic of a policy which may be traced even to our own times. "My lord," said her majesty, "I have too much love to my poor people, who obtain their bread by the employment of knitting, to forward an invention which will tend to their ruin, by depriving them of employment." It is hardly necessary to remark, that, at the time when the queen made this generous resolve, only the upper classes could afford to wear stockings, on account of their high price; but the introduction of the stocking-frame increased production to such an extent, that stockings came to be regarded as a necessary article of dress by all classes of the community, thereby increasing the number of persons engaged in producing them many hundred fold, as compared with those engaged in knitting.

In the Stocking-Weavers' Hall in Red Cross Street, London, is a picture representing a man pointing to a stocking-frame, and addressing a woman who is knitting. There is the following inscription to this picture: "In the year 1589, the ingenious William Lee, Master of Arts, of St. John's College, Cambridge, devised this profitable art for stockings (but being despised, went to France), yet of iron to himself, but to us and others of gold; in memory of whom this is here painted."

The idea of devising the stocking-frame is said to have occurred to Lee, while courting the lady whom he subsequently married. The damsel being constantly engaged in knitting, the young man, from watching the dexterous movements of her hand, conceived the idea of making artificial fingers for knitting many loops at once. From this time the ardour of invention took full possession of his mind. Success as an inventor did not, as it now generally does, involve success as a manufacturer. After many fruitless attempts to introduce his machine in this country, he sought refuge in France; and, under the auspices of the prime minister of Henry IV., established his frames at Rouen. Just as his plans were apparently about to succeed, the king was murdered, Lee was proscribed as a Protestant, and being forced to conceal himself in Paris, died there in poverty and distress. The workmen whom Lee had taken to Rouen, returned to London; and through their means a company was formed, which afterwards became a corporate body.

It is not necessary to trace the steps by which the ingenious machine, which was "of iron" to the inventor, "but to us and others of gold," came into general use; but we will at once proceed to a description of the machine itself.

Knitting, which is imitated by the stocking-frame, is performed by a couple of straight wires called *knitting-needles*, and the operation consists in forming a series of loops upon one needle and inserting them within another series formed upon the other needle. This operation is brought about by four movements. 1. Pushing the right-hand needle through the first loop of the left-hand needle; 2. Turning the thread once round the right-hand needle, in order to form a new loop; 3. Drawing the new loop through one of the former series; and 4. Pushing the old loop off the left-hand needle. When one row of loops is completed, the needles change hands, and a new course is commenced.

In knitting by the stocking-frame, the number of needles may vary from fifteen to forty in an inch, according to the fineness of the work. They are made of iron wire (fig. 213), with a hook or barb at the end, and a cavity in the stem, beneath the bar (fig. 214), to receive the point when pressure is applied on the hook, by the edge of a *presser-bar*, a section of which is shown in fig. 213, by which means the barb becomes a closed eye. Now suppose a number of these needles fitted into the frame side by side, as in fig. 215, the operation of the machine is to form of the single thread R, a series of loops, S S, and then to draw them through a series of other loops previously formed. The loops are formed by levers called *jack-sinkers* and *lead-sinkers*. The jacks, *h*, fig. 216, are horizontal, and move upon a common centre, each having a joint from which hangs a sinker of thin polished iron plate. A jack and a sinker is assigned to every alternate needle in the frame, the sinkers hanging between them as in fig. 217. The other ends of the jacks are secured by small iron springs, *k*. The lead-sinkers resemble the jack-sinkers, but are differently attached; for while the jack-sinkers admit of being raised or lowered separately, the lead-sinkers are all fixed to what is called a sinker-bar, and must be raised or lowered altogether. The lead-sinkers are placed alternately between the jack-sinkers, so that between every two sinkers there is a needle. When the jack-sinkers are raised, so as to bring their *nips*, *f*, above the level of the needle, the thread is loosely thrown under them, so that on lowering the jacks a series of loops are formed as in fig. 215; but if the jacks were all lowered at once, there would be danger of destroying the thread. This is prevented by a piece of metal, *m*, fig. 216, called the *slur*, which moves upon a bar, *l*, called the *slur-bar*, extending beneath all the jacks. By making the slur travel under the jacks, only one jack-sinker is lowered at a time, and the loops are formed between the needles, not all at once, but in succession. But the loops thus formed are of double the depth required; and to bring them to the proper size, and to distribute them between every two needles, the weaver depresses the lead-sinkers all at once, and their nips, *f*, carry down the thread between the remaining needles. While this is being done, the jack-sinkers are made to rise up as much as the lead-sinkers descend, so that the loops thus become of the same size. This row of loops is next driven back upon the needles to S S, fig. 215, so as to come below the arch or opening of the sinkers S S, figs. 216, 217. Here the loops are entirely removed from the action of the sinkers, and the workman proceeds to form a new row in front of the former. The second row of loops is then brought forward so as to be under the barbs or hooks of the needles. The presser-bar is next made to close the barbs with the thread within them: the first-formed loops are now brought forward from under the arch, upon the closed needles, and are made to pass over the ends of the needles and over the newly-formed loops within them, so that the loops of what was the upper or last course of the finished work become secured, and the loops under the barbs now become the upper course, and are preserved from unravelling by the needles, one of which passes through each loop, and these loops will not be drawn off from the needles until there is another row of loops prepared and ready to be drawn through them.

It may assist the description if we now recapitulate the various movements of the frame. Supposing the weaver to have put back the work on the needles, preparatory to another course, the first movement is the *gathering of the thread*. The thread is lightly extended across the needles, beneath the nips *f*, of the sinkers; and, by pressing the slur treadle, the jack-sinkers are depressed, one by one, so as to form double loops: this is called *drawing the jacks:* the second movement is called *sinking*. The lead-sinkers are depressed and the jack-sinkers raised, whereby the thread is carried down into a loop between every two needles. The third movement is to bring the thread under the barbs of the needles. The fourth movement is to bring the work forward from the stems of the needles towards the barbs. The fifth is to close the barbs, by the pressure of the presser-bar, and to draw the loops last made through the finished loops of the work. The finished loops are drawn over the barbs, and quite off from the needles. This movement draws the finished loops over the loops last made, which remain in the barbs.

For cotton hose the thread is wound upon bobbins, as shown in fig. 212, where the hanks of thread are spread over reels, and the thread passes through metal eyes to the bobbins. For silk hose the bobbins are placed in a barrel, fig. 218, containing a little water, the evaporation of which keeps the thread sufficiently damp for working. The thread is drawn out through a hole in the cover of the barrel, as shown in fig. 218.

A circular loom, fig. 211, has of late years been introduced; and the amount of work it is able to perform is prodigious. A machine with four feeders and 1,200 needles on the circumference, will make 80 revolutions, or 96,000 loops, per minute.

XIII.—HATS.

The production of a beaver hat depends on the curious property possessed by certain animal fibres of matting together into a kind of cloth called *felt*, and the process by which this is done is called *felting*.

A fibre of lambs' wool examined under the microscope presents the appearance represented in fig. 219. The jagged edges of cleaned wool, when subjected to gentle friction assisted by moisture, lock into each other, or felt together, a property which was probably known at a remote period; although there is some doubt whether the *lana coacta* used by the ancients as cloaks for the soldiers, for corslets and horse furniture, was true felt. Wool is not the only material capable of being felted, as will be seen by the structure of various descriptions of fur represented in figs. 220 to 223.

There are three descriptions of hat prepared by felting: first, the *beaver hat*, properly so called, consisting of a body or foundation of rabbits' fur, and a beaver nap. Second, the *plate-hat*, in which the body is of lambs' wool, *plated* or napped with musquash, neutria, or some inferior fur. Third, the *felt hat*, which is a wool body without a nap.

In making a beaver hat, a *hat body*, or foundation of wool is taken. This is in the form of a conical cap, represented by the darker figure in fig. 227. The workman weighs out one ounce of beaver down, a quarter of an ounce of musquash, and the same quantity of cotton wool. These materials being placed on a table, fig. 224, are spread out and mixed by the operation of *bowing*, as in the case of cotton (fig. 7). The bow is held in the left hand, and is attached by a cord to a beam above, so that it may be held at a proper distance; and then, with the knob of a wooden pin, the man sets the string of the bow vibrating among the fibres, the effect of which is to cause them to fly into the air, and in falling to occupy a much larger space than they did before. To prevent them from being too much dispersed, a wicker frame called the *basket*, shaped like a fire-guard, is set up on end, with its concavity towards the fur. The bowing is repeated two or three times, until the fur is spread out into a large oval *sheet of napping*, as it is now called. It is then pressed down with the hands, and afterwards with a skin of leather, called the *hardening skin*. It has now the appearance of thin flannel; and is of the form represented at No. 1, fig. 228. It is then folded into the form No. 2, fig. 229, and then into that of No. 3. The woollen hat body, fig. 227, is then placed on No. 3, and the portions of napping not covered with the body are torn away. These are bowed again into another sheet of napping, which is afterwards added to the crown of the hat, which, having to be distended out of a conical body, must necessarily be stretched, and thus require an additional quantity of fur.

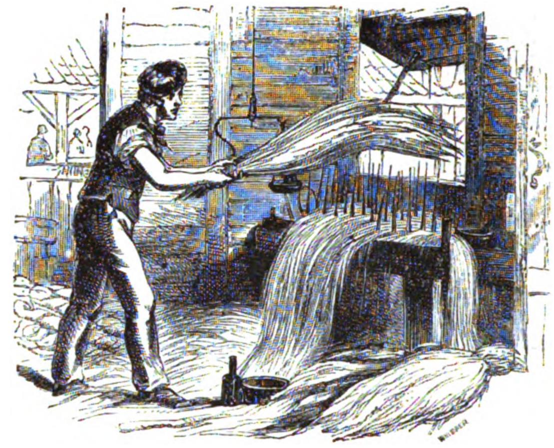
The operations are next transferred to the *hat-battery*, fig. 225, which consists of a boiler surrounded by sloping mahogany sides, and containing water acidulated with a little sulphuric acid, together with beer-grounds or oatmeal. The conical hat-body is held in the hot liquor, and when sufficiently soft is placed on the plank, and is covered with a portion of the beaver napping. It is then turned over, and the remaining portion of the napping is made to cover the other side. By means of a brush, a roller, and a piece of wood covering the palm, called a *glove*, the nap body is worked about for a considerable time. The fur soon begins to strike into the woollen felt of the hat-body; but the cotton wool, which is incapable of felting, comes away, and shows that the fur has properly combined with the body. Shape is given to the nap-body by drawing it over a wooden cylindrical block; and by dint of much working and pressing, the cone becomes nearly cylindrical in shape. And lastly, the brim is worked to the proper form.

In some cases the beaver is formed into what is called a *pull-over*, for which purpose the sheet of napping is formed into the shape of a hat cone, and is folded up with a triangular piece of brown paper, fig. 227, to prevent the opposite surfaces from coming in contact. The hat cone, fig. 227, is then placed on it, and they are worked together by a process called *basoning*, a metal plate or bason being formerly used instead of the brown paper.

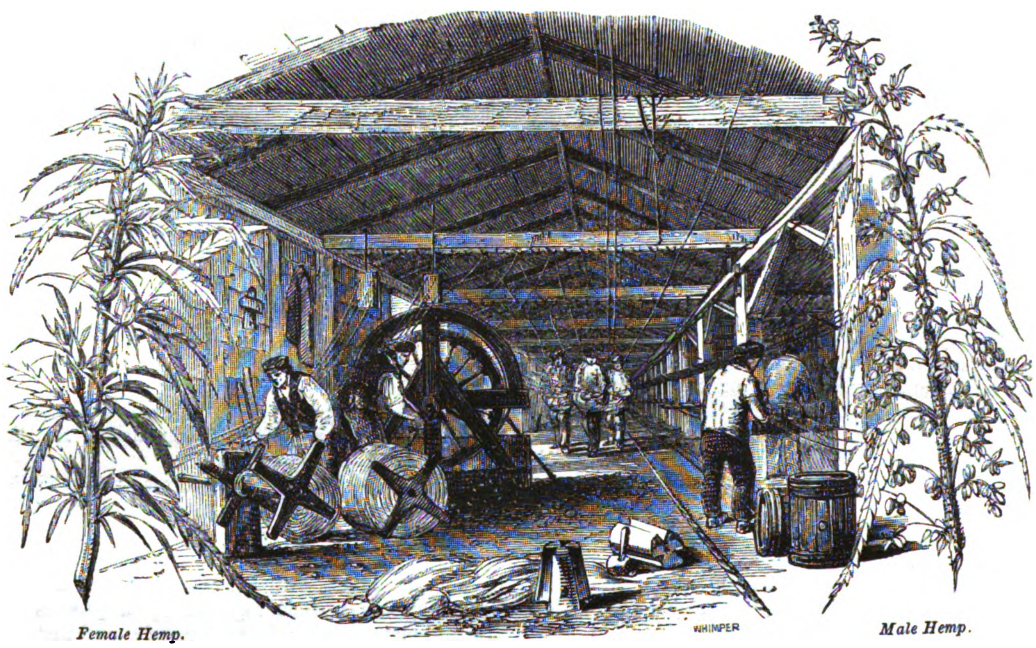
The beaver hats are next combed, and the tips of the hairs cut off with a pair of shears; after which they are mounted on blocks, suspended in an iron frame, and lowered into the dye copper, fig. 226; after which they are smoothed and finished by means of warm and damp hair brushes, hot irons, and a plush cushion, called a *velour*. *Trimming*, *binding*, and *lining*, and lastly *blocking*, or giving a modish shape to the hat, are the finishing operations.

The silk hat, which has now for the most part taken the place of the beaver, is produced in a much simpler manner. The body is formed by cementing layers of calico upon a hat-block, fig. 230, consisting of five pieces; and when the brim is attached, the whole is covered with cement, and then covered with a silk plush, manufactured for the purpose, and made to adhere by the application of moisture and heat.

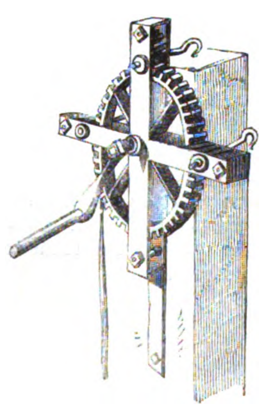
231. RETTING, BREAKING, HECKLING, AND DRYING HEMP.



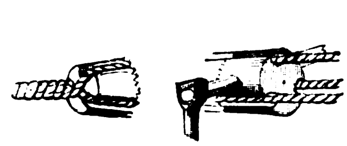
232. HECKLING MANILLA HEMP.



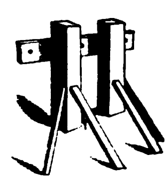
233. ROPE-WALK—SPINNING YARNS.



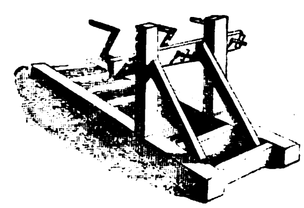
234. WHEEL FOR TWISTING STRANDS.



235. TOPS FOR LAYING STRANDS.

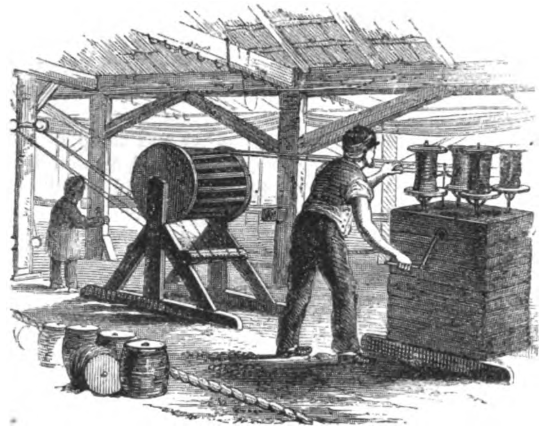


236. TACKLE BOARD.

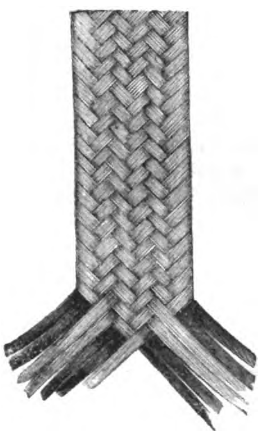


237. SLEDGE.

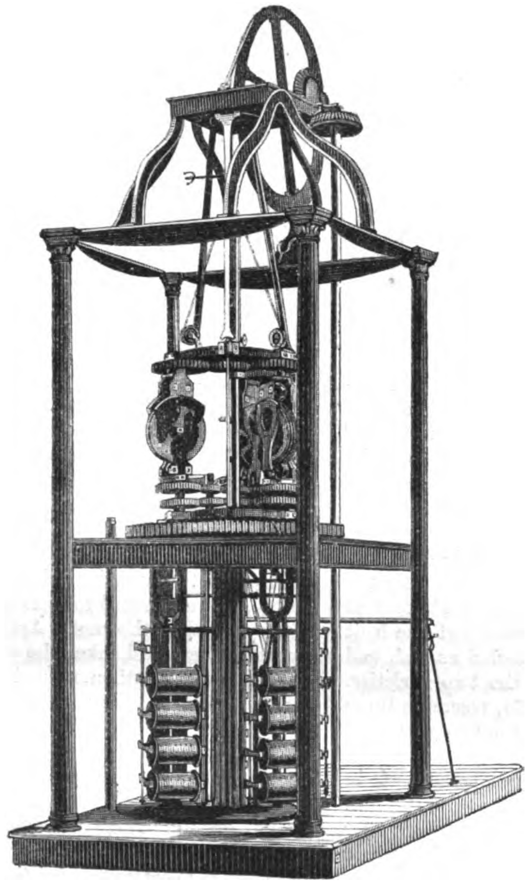
238 SPINNING YARNS.



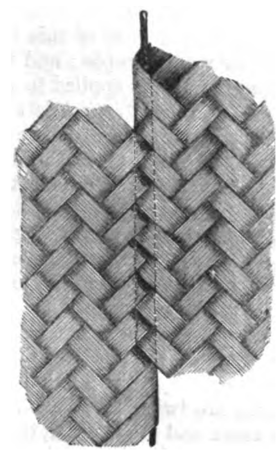
239. REELING YARNS.



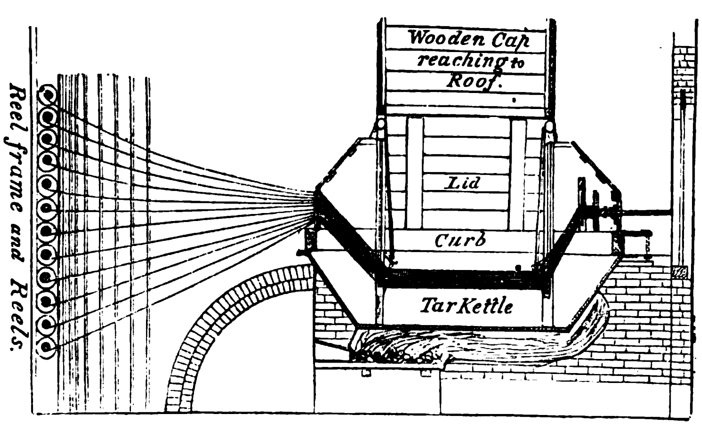
243. ITALIAN STRAW-PLAIT.



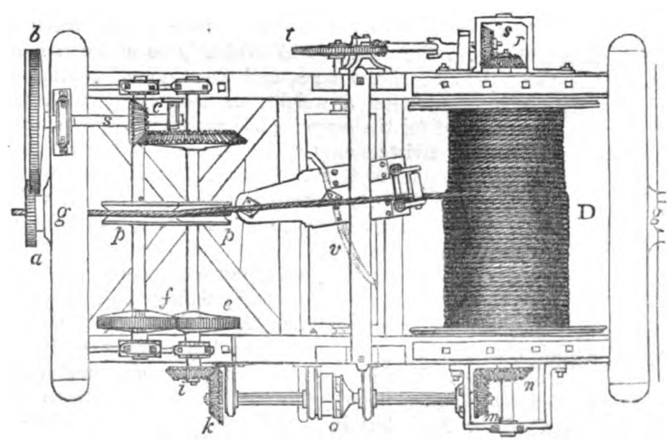
240 ROPE-MAKING MACHINE,



244. METHOD OF JOINING.



241. TARRING YARNS.



242. REGISTER MACHINE.

XIV.—ROPES AND CORDAGE.

If all the cordage, great and small, of a first-rate ship of war were tied together, end to end, it would measure 43 miles; it would weigh 78½ tons, and would cost 3,276*l.* sterling. Smaller vessels, whether of the navy or of the merchant service, cost similar sums for their cordage, in proportion to their size. In a free maritime country like the British Isles, whose ships visit every habitable coast and ascend every navigable river of the earth, the importance of the rope manufacture can scarcely be over-estimated. A portion of that busy shipping is employed in bringing to these shores the raw material for those innumerable lines, which give such a trim and beautiful appearance to a well-rigged vessel, to say nothing of the numerous other uses to which ropes, cord, string, &c. are daily and hourly applied. In the year 1859, there were imported into the United Kingdom 1,088,249 *cwts.* of hemp; and 1,071,731 *cwts.* of jute and other vegetable substances of the nature of hemp. Considering the importance of the manufacture, we see the wisdom of our Legislature in making these substances free of duty.

Hemp is the principal but not the only material for rope-making. The husk of the cocoa-nut, the fibres of the wild banana, various kinds of tough grass, horse-hair, wool, thongs of leather, metal wires, &c. are all used as materials for ropes. The native rushes or *junci* of this island were employed at an early period for making ropes; and the practice is perpetuated in the term *junk*, which is applied to worn-out ropes.

Hemp (*Cannabis sativa*) is stronger and coarser in the fibre than flax; but its uses, culture, and management are nearly the same. It is an annual plant, usually about five or six feet in height; and from the circumstance of the flowers and the fruit growing on separate plants, hemp is distinguished as *male* and *female*. The supporters to fig. 233 represent the two varieties. The *retting, breaking, heckling*, and *drying*, fig. 231, resemble those operations already described under flax, so that we may proceed at once to the business of the manufacture.

The word *rope* properly belongs to cordage above an inch in circumference, the smaller kind being named *twine, cord*, and *line*. In making a rope, the hemp is first spun into *yarn*. A number of yarns are twisted into a *strand*, three strands twisted together form a *rope*, and the twisting together of three ropes forms a *cable*.

The object of twisting the fibres is to produce sufficient compression to prevent them from sliding over each other when a strain is applied. Twisting does not increase the strength of the fibres, but, on the contrary, greatly diminishes it. A rope formed by arranging the fibres side by side and fastening them at the ends, is much stronger than the same number of fibres twisted into a compact cord. In the one case each fibre bears its own share of the strain, and the strength of the bundle is that of the sum of the strengths of the separate fibres. In twisting the fibres, those on the outside will evidently be strained more by the twist than the inner ones, and, consequently, will be less efficient in supporting a weight, or resisting a pull. In an experiment tried for the purpose, the untwisted fibres supported 98lbs., and the twisted only 65lbs., showing a loss of strength from twisting equal to 33lbs. But as twist is necessary to get length, it is adopted, subject to the maxim, that all twisting, beyond what is necessary to prevent the fibres from slipping on each other, is to be avoided.

The first operation in the manufacture of a rope is *heckling*, for the purpose of separating and straightening the fibres, so that they may run freely in spinning. A weighed quantity of hemp, sufficient to form one yarn 160 fathoms long, is thus combed out at each operation. The *heckle* (fig. 232) consists of a number of steel prongs, set up in a board with the points upwards, as already described for flax; but in heckling hemp, a little whale oil is applied to the points from time to time to assist the operation. Each heckled portion is tied up into a bundle, called a *tow of hemp*, one of which is represented in the right-hand corner of fig. 232.

The hemp thus prepared is next spun or twisted into yarn; the spinning is usually carried on in a long covered walk, called the *spinning-walk* (fig. 233), one end of which is called the *head*, or *fore-end*, and the other the *foot*, or *back-end*. At one end is a *spinning-machine*, consisting of a wheel, over which passes a band, which gives motion to a number of *rollers* or *whirls*, furnished with little hooks, which are set rapidly spinning by turning the wheel. As many spinners may work together as there are whirls in the frame. Each spinner takes a tow of hemp, and wrapping it round his body, draws out from the face of the bundle as many fibres as he thinks necessary for the size of the yarn, and attaches the *bight* or *double* of the fibres to one of the whirl-hooks, while an assistant turns the wheel, and throws *twist* or *turn* into the fibres. The spinner (figs. 233 and 238) has a piece of thick woollen cloth in his right hand, the end of which hangs over the fore-finger. With this he grasps the fibres as they are drawn out, pressing them firmly between his two middle fingers. He walks backwards towards the foot of the walk, and with his left hand regulates the supply of the fibres, so as to make the yarn of equal size, the thickness of the yarn depending on the quantity of hemp which the spinner allows to pass through his hands in a given time, and also on the rapidity with which the hook is made to rotate. As the yarn increases in length, the spinner throws it over hooks fixed to the under side of the rafters of the roof. Arrived at the lower end of the walk, a man at the wheel takes the yarn off the hook and fastens it to a reel, which is then turned round, while the spinner walks slowly in, keeping the yarn stretched all the way.

The next process is *tarring*, for which purpose 300 or 400 yarns are placed side by side, and passed through hot tar. They are dragged out through a hole called a *grip*, or *sliding-nipper*, which presses the tar into the yarn, and gets rid of the superfluous portion. Tarred cordage has not the strength of untarred; but it resists the wet better.

The next operation is *twisting* or *laying* the yarn, either tarred or untarred, into strands. The *laying-walk* may be under the same roof as the spinning-walk (fig. 233). At the head of the walk is a *tackle-board* (fig. 236), which is a plank supported by strong upright posts, and pierced with three holes corresponding to the number of strands in a rope: *winches* or *fore-lock hooks* work through these holes. The smaller strands are twisted by the wheel (fig. 234). The yarns, preparatory to laying, are attached to posts at the side of the walk, as shown in fig. 233, or they are wound upon reels, as in fig. 239. As the yarns are twisted together into a strand, they are attached to a moveable *sledge* (fig. 237), the upper part of which has a *breast-board*, corresponding to the tackle-board. The sledge is kept steady by being loaded with weights. The proper number of yarns for each strand is attached to the hooks of the tackle-board, and of the sledge. The latter is then pulled backwards until the yarns are stretched tight, when the hooks, both of the tackle-board and of the sledge, are heaved round in a direction contrary to the twist of the yarn, by which means the three bundles of yarn are formed into a strand. The shortening of the yarns, by the twisting, draws the sledge forward; and when the strand is *full hard*, or has enough *hard* in it, as the twisting is called, the process is complete.

The next operation is *laying*, or twisting three strands together to form a rope; for which purpose the three strands are attached to the middle hook of the tackle-board, and all three are inserted

into the grooves of a piece of wood called a *top*, fig. 235. On twisting the three strands together, the top is forced forward and the rope is formed. In the laying of three strands together, the rope is said to be *hawser-laid*. In this process, which is called the *first lay*, each strand consists of as many yarns as are necessary to give the required thickness to the rope. The *second lay*, or *shroud hawser-laid rope*, consists of four strands, with a straight loose strand or *core-piece* running through the centre, to render the rope solid. In the *third lay*, or *cable-laid rope*, three hawser-laid ropes, each formed of three large strands, are twisted, or laid together, so as to form one gigantic rope or cable. This, however, has of late years been superseded by the chain cable.

Machinery has been applied with considerable success to the manufacture of ropes. We do not pretend, of course, in these short essays, to present more than a very few rough outlines of the important subjects of which they treat; and our outline, such as it is, often refers to one machine, or set of machines, while we pass over others which produce similar results by different means, but quite as efficiently. In noticing Captain Huddart's *Register-machine*, we wish to refer to it as one out of several inventions for accomplishing the same object.

The yarns, having been spun by machinery similar in principle to that already described for cotton and flax, are wound upon reels, and mounted in a *frame* (fig. 241), whence they proceed through a tar-kettle, and passing through certain plates, which get rid of the superfluous tar, are passed through a tube, and thence to the registering-machine, fig. 242, which twists them into strands. This consists of a square frame of wood, supported horizontally upon two small gudgeons, *g g*, upon which the frame, with the machinery contained within it revolves. The strand enters this frame through one of the gudgeons, and passes under and over two pulleys, *p p*, on its way to the winding-drum. Motion is given to the pulleys by connecting the pinion *a* with the toothed wheel *b*, the spindle of which, *s*, carries a bevel-pinion, *c*, which works another bevelled wheel attached to the spindle that carries one of the pulleys, while the toothed wheel, *e*, in gear with *f*, gives motion to the other pulley. Now it will be evident that, as the whole frame revolves, the yarns from fig. 241 will be twisted into a strand, and that the motion of the pulleys *p p* will drag it forward through the register tube. The same motion which produces these operations winds the finished strand upon the drum *D*. The motion is given to the drum by connecting the small mitre pinion *i* with a similar pinion *K*, and this is connected by means of the spindle with the pinions *m* and *n*, the latter of which is fixed to the axis of the winding drum. As the frame revolves, the two pulleys and the winding drum thus have their own distinct revolutions. As the coiling advances, the increased size of the drum would give an increased strain to the strand were it not provided for by dividing the spindle *o* into two equal parts, uniting them by means of a clutch at *o*, which slips upon itself whenever the drum tends to overwind the pulleys, and thus the drum remains stationary for a moment, while the strand slackens a little. In order to wind the strand in regular coils upon the drum, the opposite end of the axis has a mitre pinion, *r*, in gear with a similar one, *s*, attached to a short spindle, which is furnished with a universal joint acting upon the forked end of an oblique spindle which bears an endless screw, working into a toothed wheel, *t*; this wheel is fixed upon the end of a spindle placed across the frame, carrying a wooden roller, *v*, which thus acquires a slow rotatory motion. Upon this roller is a long endless groove, shown partly by the dotted lines; in this groove there fits a stud, which projects from the under face of a guide frame. As the drum revolves, the roller slowly moves, and shifts the guide frame alternately from side to side. The strands thus formed are now ready to be laid into ropes, an operation which is effected by a *rope-laying machine*.

The machine represented in fig. 240 lays the yarn into strands, and the strands into ropes, at one operation.

The cordage made for the use of the British navy is distinguished by a coloured worsted thread in the centre of each strand, and every combination of strands or rope is also distinguished by a simple yarn of peculiar make laid in its centre.

XV.—STRAW PLAIT.

We have now brought to a conclusion our notices of spinning and weaving. We may, however, refer to an important branch of industry which belongs to that kind of weaving called *plaiting*. The manufacture of straw hats attained great perfection in Italy more than two centuries ago. But it was not until the long-continued war with Napoleon arrested the import trade, that our home manufacture rose into importance. The Tuscan straw is from a variety of bearded wheat (*Triticum turgidum*), which is grown in Tuscany for the sake of the straw: this is pulled while the ear is in a soft milky state, the corn having been sown close, so as to produce it in a thin, short, and dwindled condition. It is dried by exposure to the sun, then laid up in bundles and stacked for about a month, after which it is bleached by exposure to moisture, light, and air. The bleaching is completed by means of the fumes of sulphur.

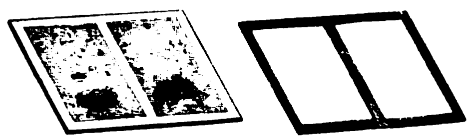
In the Italian method of plaiting, the straws having been sorted as to colour and thickness, thirteen are usually selected, tied together at one end, and then divided into two portions, six straws being turned to the left and seven to the right, so that the two portions of straw may form a right angle. The plaiting then proceeds in the manner represented in fig. 243. The plait is formed in pieces of great length, which are adjusted in spiral coils, with their adjacent edges knitted together, so as to form the large circular *flats* which were formerly extensively exported from the north of Italy. Fig. 244 shows the method of knitting the edges togther; the dotted lines indicate the edges of each piece of plait, and show how far the angular folds or *eyes* of one piece are inserted into those of the adjoining piece. The thread by which the two rows are held together is entirely concealed in the plait.

The British straw-plait district is in Bedfordshire, Hertfordshire, and Buckinghamshire; the manufacture is also carried on in Essex, Suffolk, and elsewhere. There are many varieties of plait in general use, such as *Whole Dunstable*, consisting of seven entire straws; *Patent Dunstable*, or *Double seven*, formed of fourteen split straws; *Devonshire*, formed of seven split straws; *Luton Plait*, formed of double seven, but coarser than patent Dunstable: *Bedford Leghorn*, formed of twenty-two, or double-eleven straws; *Italian*, formed of eleven split straws. There are several varieties in *Fancy Straw Plait*, such as the *Back-bone*, of eleven straws; the *Lustre*, of seventeen straws: the *Wave*, of twenty-two straws; and the *Diamond*, of twenty-three straws; nor must we forget to mention the *Rustic*, of four coarse split straws, and the *Pearl*, of four small entire straws.

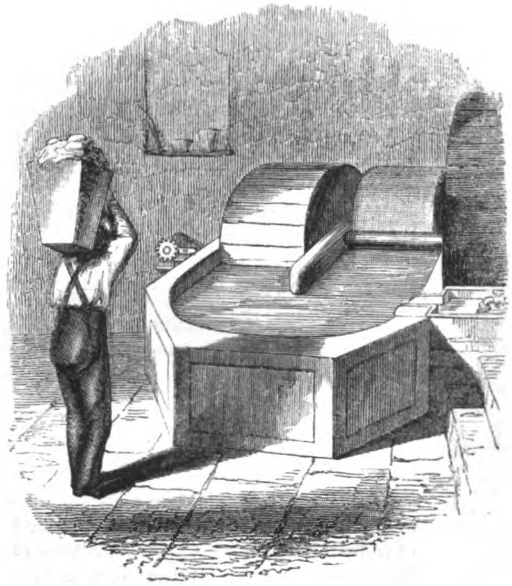
About 70,000 persons are engaged in the production of straw-plait, which still maintains its ground notwithstanding the use of silk and other materials foı bonnets. This arises from the circumstance that the whole of the female population in Great Britain wear bonnets, which is, probably, not the case in any other part of the world, with the exception of North America.

245. PAPER MILL.

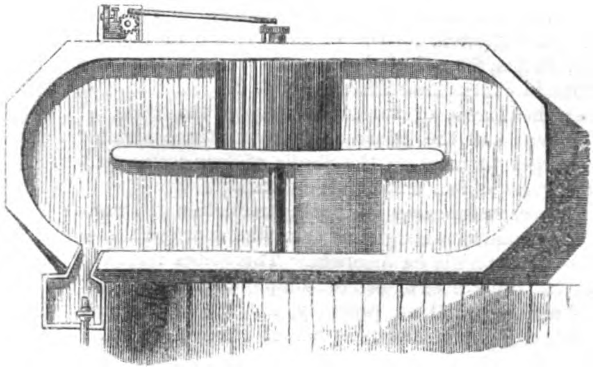
246. RAG-CUTTERS AT WORK.



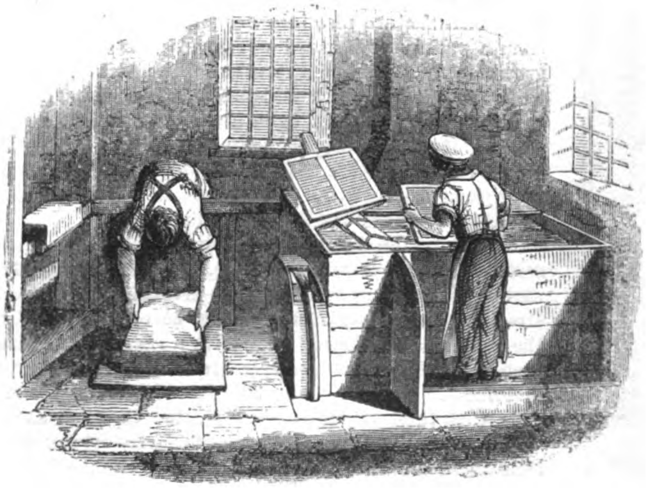
248. PAPER MOULD AND DECKLE.



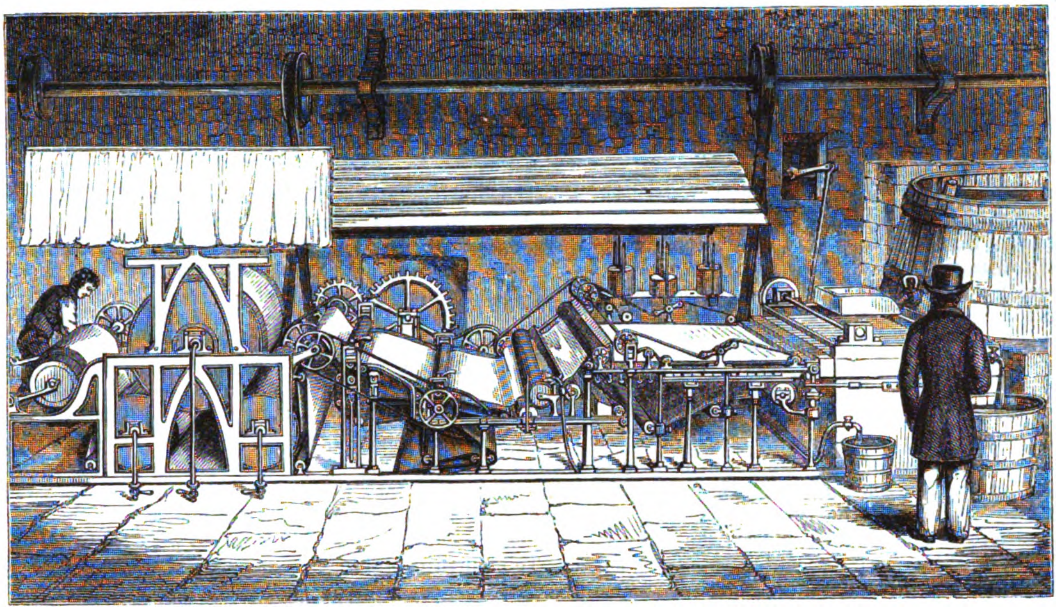
247. WASHING ENGINE.



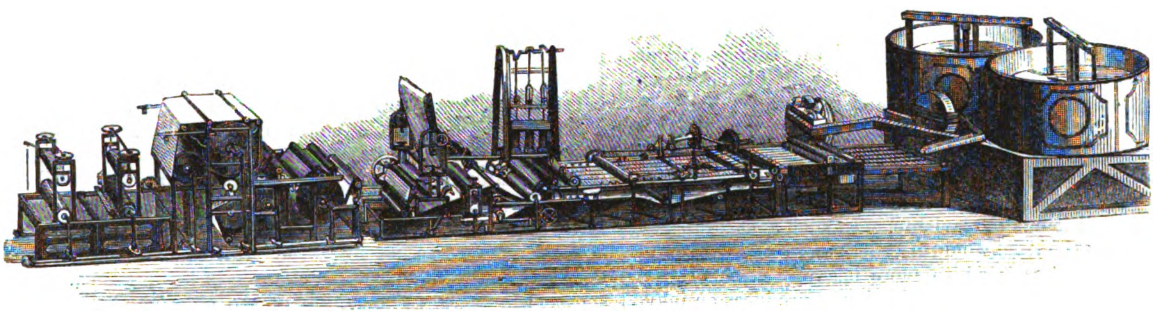
249. BEATING ENGINE



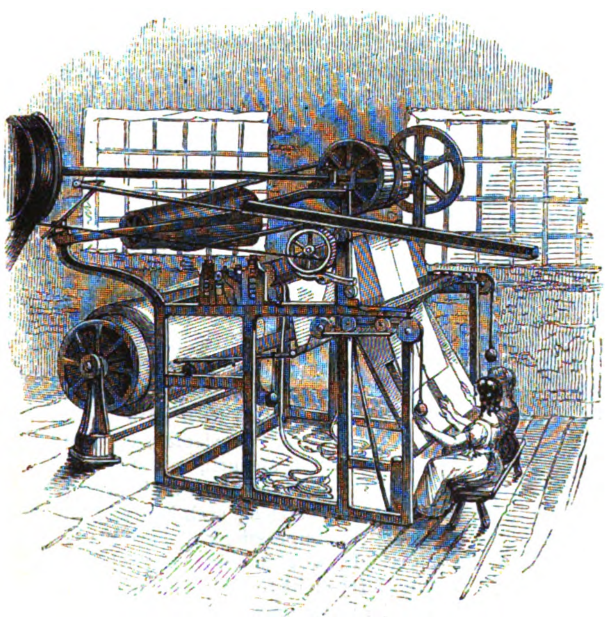
250. MAKING PAPER BY HAND.



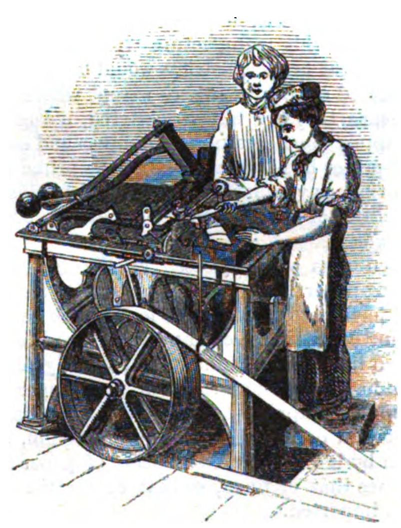
251. PAPER-MAKING MACHINE.



252. ANOTHER FORM OF PAPER-MAKING MACHINE.



253. PAPER-CUTTING MACHINE.



254. ENVELOPE-FOLDING MACHINE

XVI.—PAPER.

The manufactories which have hitherto engaged our attention are, for the convenience of markets for the raw material, and for the sale and transport of the finished product, situated in densely crowded cities and towns, where the engineer and other persons subsidiary to the great staple trade of the place reside, and all more or less seem to be urging on one or other branch of the great manufacture. A stranger, walking through one of these vast manufacturing centres, has before his eye at every turn one of those huge factories which have been erected evidently with a view to utility rather than beauty of proportion (although in some cases both have been happily combined). The tall chimneys pour out their volumes of smoke, often in despite of the smoke-consuming apparatus with which the furnaces are provided. Everywhere do we hear the heavy respirations of the steam-engine, the pulsations of endless machinery, the rattle of spindles, and the whirl of wheels: we are conscious of incessant activity, and feel almost ashamed of strolling about as an idle spectator in the midst of a toiling population. We leave the town by roads which are ground to dust by the endless traffic, and find the neighbourhood equally busy. Instead of farms and rural scenes, we have workshops, forges, tall chimneys, canals, and railroads; and should there be a river, which once sparkled in the bright sunshine, it has long since been yoked to labour, and is not allowed to descend through a foot of its course without having work to do. Its banks are crowded with bleach-works, dye-works, cotton-mills, water-wheels, and machinery; and lest it should fail in its laborious efforts, catch-pools are erected at various points of its course for arresting the rains of heaven and the surface waters of earth, so jealous is man lest the poor river should have a drop of water too much, or before its time, or should expend what it has too lavishly. In such a hard-worked river the trout and the dace would be idlers and interlopers, and they have long since departed to more leisurely streams: the refuse of the bleach-works or of the dye-house produces an inky, murky mixture which is intolerant of life—of anything, in short, but work.

We are now about to visit a manufactory, the hum of whose machinery blends melodiously with the song of birds, with the rustling of trees, with the gurgling waters of the trout stream, with rural sights and sounds, pleasant to the eye and refreshing to the soul. The paper-maker requires an abundance of pure water; in few manufactories is so much employed, and in none is its quality so important as in the production of fine paper. To attempt to carry on this manufacture with the coloured or mineralised water of peat or iron districts would be hopeless. Paper-mills may be situated almost anywhere except where other mills abound; and hence they are widely scattered, inasmuch as pure streams are happily more common than mines and collieries. Hence, too, water-power has continued to be the prime mover in these mills, more than any other; although many mills have outgrown the capabilities of their streams, and have added the steam-engine to their works.

Linen rags were selected as the material for writing and printing-paper, as being the most worthless of all refuse; and such they continued to be so long as the demand for writing and printing did not exceed the supply furnished by the whole wear of linen in the same country. But the English, the French, and the Dutch have long since required more paper than their worn-out clothing can supply; so that they have to import rags, while the exportation of rags from France, Belgium, and Holland is forbidden by law. The consumption of paper in England is five or six times that of linen, so that by far the larger supply of our rags is imported.

The first operations of the factory are dirty and unpleasant. The rags arrive in this country in a very impure state, and they have to be *sorted*, cut into pieces of about an inch square, buttons to be removed, and seams placed apart by themselves. The rag-cutter stands before a grating, through which the dirt and dust pass, while a sharp knife, fixed with its edge away from the workwoman, is used to divide the rags (fig. 246). The divided rags are thrown, according to their quality, into boxes at the side.

The second operation, called *dusting*, is performed in cylindrical wire cages, inclosing a revolving axis, from which spokes proceed, and the rapid motion of this axle agitates the rags so as to shake out their dust into the wooden case which incloses the cage. *Boiling* is the next operation, for which purpose the water in which the rags are immersed is mixed with lime or caustic soda.

The fourth operation is *washing*, in which the rags are partly reduced to *pulp*, by being passed between a fixed set of cutting edges and another set projecting from a revolving cylinder, called the *roll*, the upper part of which is shown in its position in the trough (fig. 249), while the appearance of the engine is given in fig. 247. The trough is divided into two parts by a partition in the middle; and the roll is furnished with a wooden covering, like that of the paddle of a steamer, to prevent the water and the rags from being scattered about. The motion of the roll draws the rags through between its own cutters and the fixed ones beneath, and then, turning them over a ridge keeps them and the water in constant circulation round the central partition. The dirty water continually overflows into a waste pipe, which is covered with wire-gauze to prevent loss of fibre, while fresh water enters by a pipe shown in both figures. In this engine the rags are reduced to what is called *half-pulp* or *half-stuff*. The colour is such as we recognise in whitey-brown paper; but by placing the stuff in a weak solution of chloride of lime, it is changed to a snowy whiteness. The action of the chlorine, however, is to impair the strength and durability of the fibre; so that wherever great durability is required, as for the books printed at the Oxford University Press, or for the paper for Government statistical records, it is preferred unbleached.

The sixth operation is a repetition of the fourth, The pulp is passed through an engine, now called the *beating-engine*, which is identical with the washing-engine, except that the cutting-blades are closer together and more numerous, and the roll revolves quicker.

Such is the material for making paper. If the operation is to be performed by hand, it is mixed with water in a vessel called the *stuff-chest*, from which it flows through a strainer, to separate knots or lumps, into a vessel called the *vat*, which contains a small stove or steam-pipe for keeping the mixture of pulp and water warm, together with a revolving wooden agitator for preventing the pulp from subsiding to the bottom. The sides of the vat are furnished with broad shelves, and the one at which the man works is called the *trepan*. Sheets of paper are formed by *casting* the pulp in a *mould*. The mould may be *laid* or *wove*, and the paper bears the name of the mould which produces it. Each mould consists of a wooden frame filled with wire like a sieve (fig. 248); in the laid mould, the wires are stretched across in one direction only, fifteen or twenty in an inch, and stiffened by thin bars of wood, crossing them at intervals of an inch and a half or less, while a stronger wire runs along each bar, and to which the other wires are fastened: impressions of both kinds of wire are seen in the paper. In wove moulds, the wire is woven into wire cloth of from forty-eight to sixty-four wires in an inch each way; this leaves the paper only slightly granulated

with no distinct lines. Each mould is furnished with a thin frame called a *deckle* (fig. 248), which is placed upon the wires within the ledge formed by the outer frame, fitting very accurately, and keeping the moulded sheet to its exact size. The maker, who is called the *vat-man* (fig. 250), dips the mould with the deckle upon it into the mixture of pulp and water, lifts it out with a gentle shake and careful levelling, to equalise the thickness of the sheet of liquid, holds it steadily for a few seconds to drain off the water, when he slides it along the trepan to his fellow-workman, called the *coucher*, at the same time removing the deckle to place it on another mould, in which he makes another sheet. However simple this operation may appear, it is really very difficult to take up 1, or 1½, or 2 oz. of pulp, and spread it equally over one of these moulds, so that the water in draining off may enable the filaments to combine or *felt* together, so as to form an even sheet, and all the sheets be of the same weight. Not only does the vat-man do this, but he will even produce two sheets at one operation in the kind of mould represented in fig. 248. The *water-mark* in the paper is formed of thin wire, sewn upon the wires of the mould, and the impression is produced by rendering the paper where it lies on it thinner and more translucent. The coucher receives from the vat-man the sheet of paper, resting on the mould with a bare margin of wires all round it where the deckle was laid, and turns it over upon a piece of felt, an inch or two larger than the sheet in every direction. To this the newly-made paper adheres; and the coucher returns the mould to the vat-man and receives the other mould with a new sheet upon it; but before taking this up from the perforated board on which the vat-man leaves it to drain, he places a second felt over the previous sheet, and upon this turns over the mould and deposits the next sheet. Thus two moulds, but only one deckle, are in use at each vat. The work proceeds until the number of felts and sheets of paper piled up amounts to what is called a *post*, usually 144 sheets, or six quires. The post is now transferred to a screw press, where it is subjected to strong pressure, and remains there until a second post is ready, when it is taken out, and a third workman, called the *lifter*, separates the sheets from the felts. In this way the three workmen—the vat-man or dipper, the coucher, and the lifter, will sometimes produce twenty posts, of six quires each, of moderately large paper in a day.

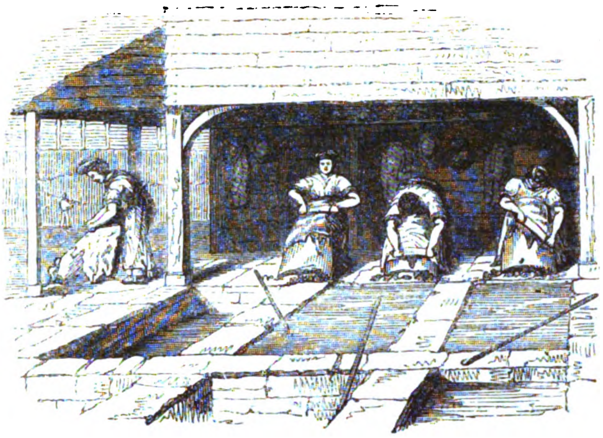
The next process is *wet-pressing*, in which the lifter piles eight or ten posts in one heap; and the sheets being now in contact with each other, instead of with the felt, become much smoother, and, on being removed from the press, can be handled without fear of tearing. For the finer kinds of paper the pressure is repeated after the heap has been re-arranged, by a process called *pack-parting* or *exchanging*, in which the sheets are re-arranged in such a way that none may be next the same sheet as before. The sheets are now removed to large lofts, where the paper is hung upon hair lines to dry. When dry, it is called *water-leaf*, and will absorb liquids freely like blotting-paper. To enable it to be written on, it is *sized*, or passed through a solution of gelatine, containing a little alum, or the size may be mixed up with the pulp in the beating-engine, in which case a compound of flour, rosin, and soda may be used. After the sizing and second drying, the paper is finished by various smoothing operations called *surfacing*. In *hot-pressing*, each sheet of paper is placed between two glazed cards or press-boards, and these between thick smooth plates of cast iron, that have been heated in an oven. A pressure of about 100 tons is then applied, the effect of which is to give a beautiful finish to the paper. The other mode of surfacing is called *milling* when performed between plates, and *rolling* or *calendering* when the paper itself touches the rollers. The plates may be of copper, of zinc, or of card, each giving its peculiar gloss. It is then passed between rollers at least three times with the paper between them. The highest possible gloss is called *glazing*, and this is produced by passing the paper many times through the roller mill. The process resembles calendering, already described (see fig. 139).

The operations of the paper-maker, such as we have described them, still apply to the finer descriptions of paper; but they are inadequate to the supply of that vast amount of printing-paper which the intelligence of the age, fostered by steam-printing machinery, requires. The inventor of the *paper-making machine* did not set to work to imitate the proceedings of the dipper, the coucher, and the lifter, so much as to see how he could produce cheap and useful paper. Instead, therefore, of making a small wire mould or sieve receive the liquid pulp at one place and carry it along to another, and there deposit it when sufficiently drained and solidified to lie on the felt, and then return the empty mould for another sheet,—instead of this interrupted and fragmentary kind of action, he conceived the idea of a continuous or endless web of *wire-cloth* (figs. 251, 252), stretched over two or more revolving rollers, receiving pulp from the vats (shown at the right-hand extremity of each figure). As the wire cloth is thus constantly travelling forwards, draining the water away in its progress, it arrives at a point where the wire-cloth turns over its extreme roller, and the web of pulp is sufficiently coherent to be taken up by a felt or blanket, which carries it on with precisely the same speed as the wire gauze, passing the pulpy mass through rollers with gradually increasing intensities of pressure, until the paper arrives at the *drying cylinders*, which, being heated by means of steam, drive off the superfluous moisture, and the finished paper is received on a revolving reel in one continuous roll of any desired length, or it passes at once to a *cutting-machine* (shown separately, fig. 253), where it is divided into sheets of the required size.

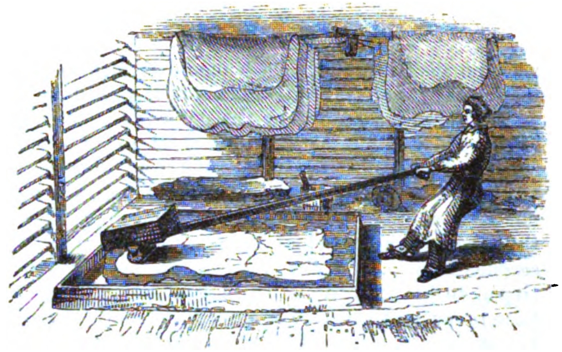
We cannot give more than this general notion of the paper-making machine, without the assistance of more precise drawings than the pictorial forms with which we have to deal; but we may just refer to a few members of the machine which are essential to its well-being. The stuff flows out of the vat through an ingenious *knotter* or *strainer*, for keeping back knots, and yet allowing the linen fibres, which sometimes approach a quarter of an inch in length, to pass through, and not lie across and choke up the apertures. Then there is a contrivance for giving a rapid jerking motion to the wire gauze, to facilitate the draining and equable distribution of the fibres. But as the water that passes through carries with it some of the fibres, it is collected below by a *save-all*, and is lifted by a *Persian wheel*, or wheel of buckets, to a sufficiently high level to flow back into the straining troughs. The edges of the paper on the wire gauze are limited by *deckle straps*, which serve the same purpose as the deckle to the paper-maker's mould (fig. 248). The draining and consolidation of the film on the wire-cloth is further assisted by allowing a portion of the wire-cloth to pass over the open tops of a couple of boxes, the air of which is exhausted by means of three small air-pumps. The pressure of the external air on the paper-film carries much of its moisture into these boxes, and greatly consolidates the layer; so much so, that at this point the pulp visibly changes into paper. Between the two boxes an embossed or perforated roller, called a *dandy*, impresses on the half-solidified film any water-mark or other imitation of the peculiarities of the old hand-made paper.

In conclusion, we may refer to the *envelope-folding machine* (fig. 254), the rapid motions of which facilitate the postal arrangements of the day, which, in the year 1859, had to deal out to the inhabitants of these islands not less than 545 millions of letters, in the following proportions:—

In England	446	millions, or	22	to each person in one year.
,, Ireland	47	,, ,,	7	,, ,, ,,
,, Scotland	52	,, ,,	16	,, ,, ,,
	545			

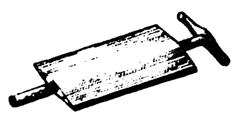


255. LIME PITS.—UNHAIRING HIDES.

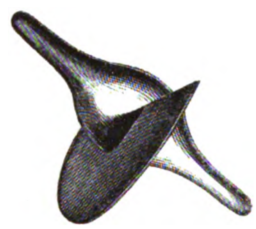


256. FINISHING HIDES.

257. THE BEAM-MAN.

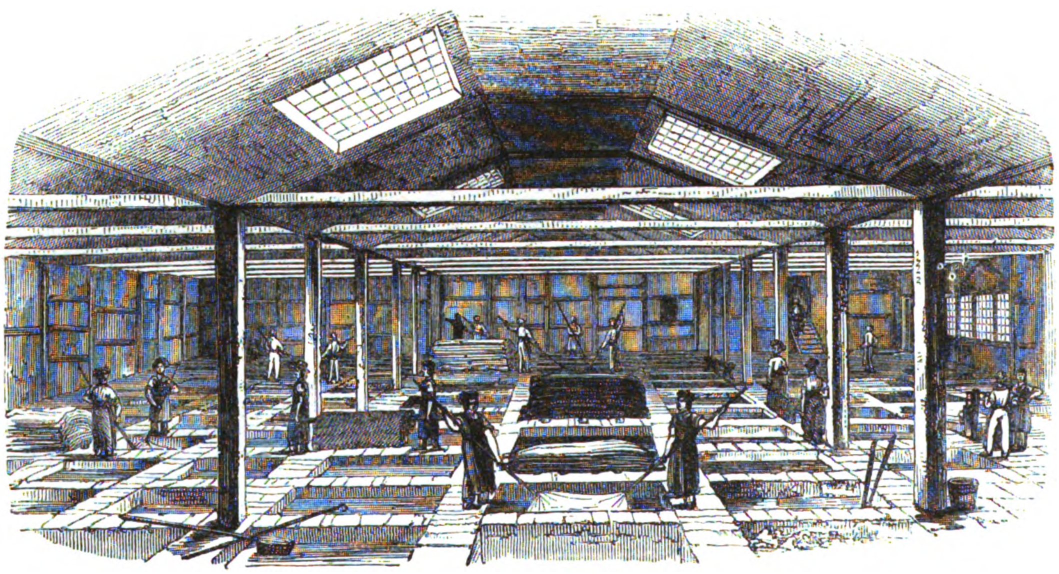


258. CURRIER'S KNIFE.

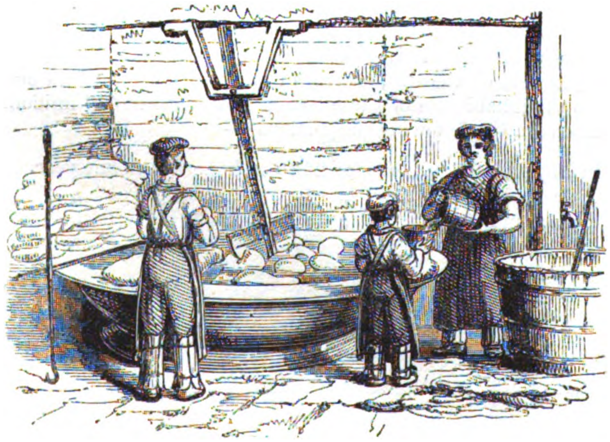


259. HALF-MOON KNIFE.

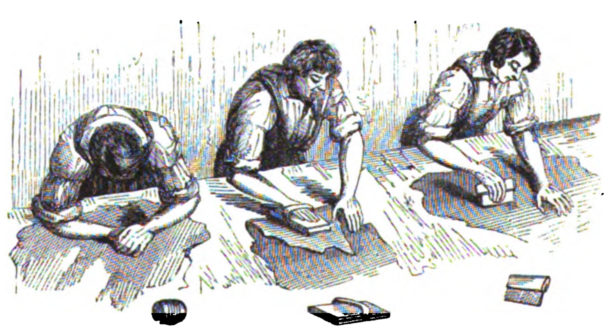
260. STAKING TAWED LEATHER.



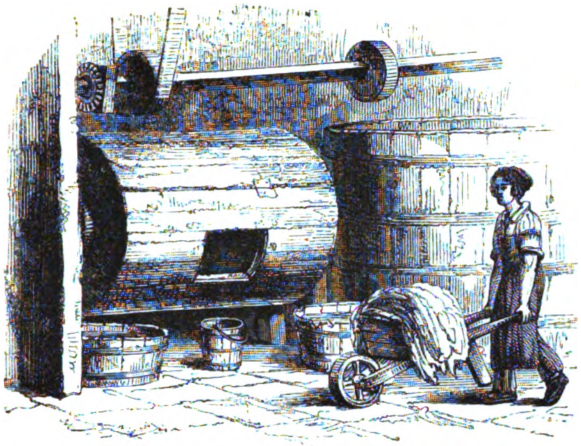
261. THE TAN PITS.



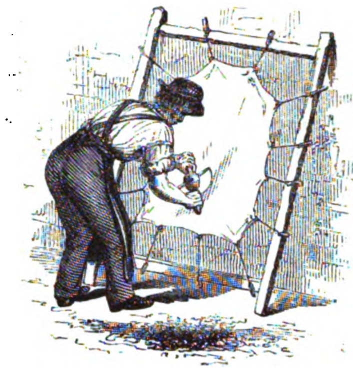
262. THE SUMACH-TUB.



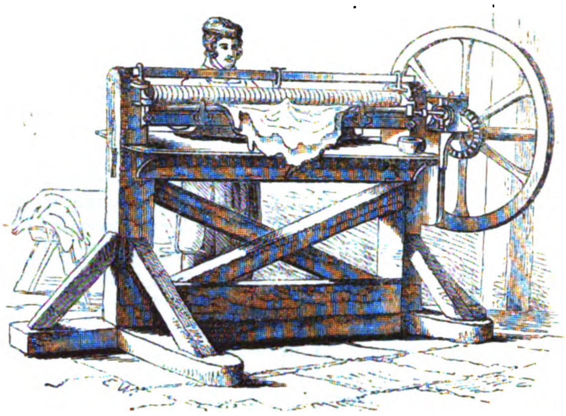
263. FINISHING THIN LEATHERS.



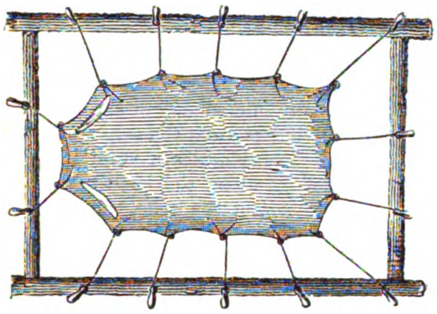
264. TAWING DRUM.



265. SCRAPING

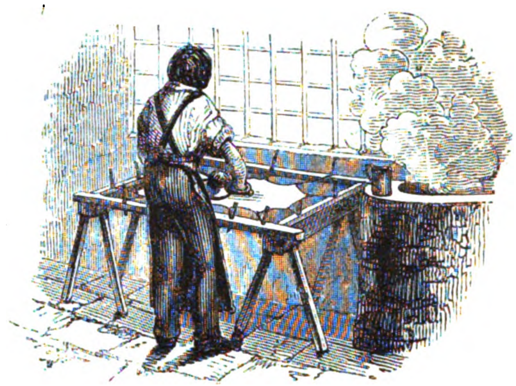


266. SKIN SPLITTING MACHINE.

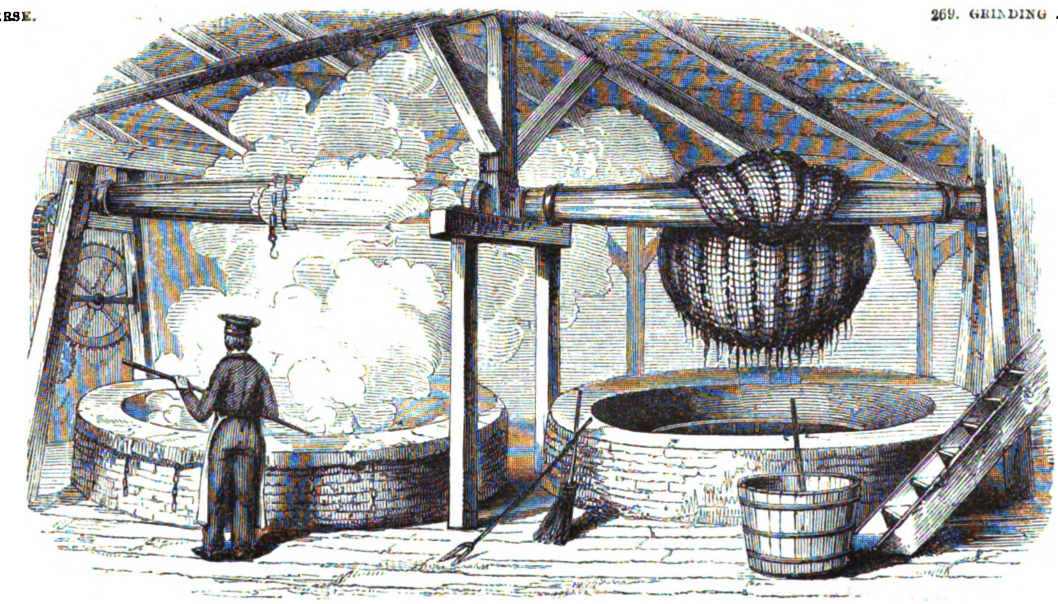


267. HERSE.

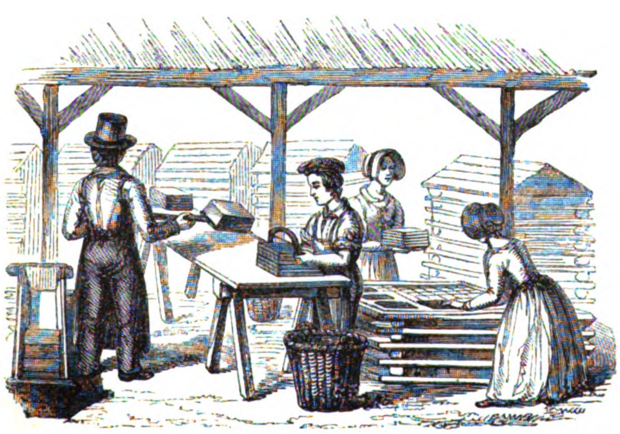
268. SCOURING



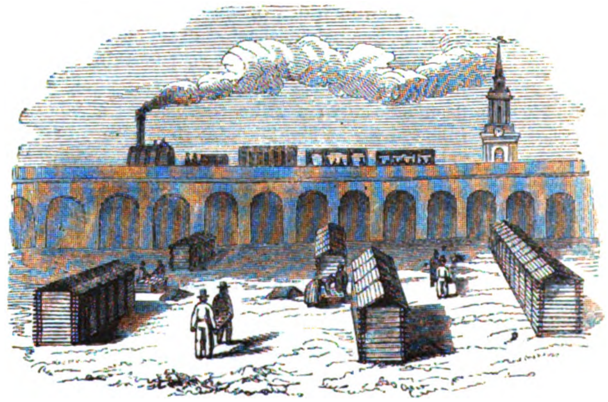
269. GRINDING AND DRAINING.



270. GLUE BOILING.



271. CUTTING OUT AND DISTRIBUTING THE GLUE.



272. GLUE-MAKER'S FIELD AT BERMONDSEY.

XVII.—LEATHER.

In a rude state of society, the skins of animals caught in the chase would be likely to form the clothing of man; but in drying, they would shrink and become horny, and when exposed to moisture, putrid. Hence the art of making a hard, unyielding substance *lith* or pliant, gave rise to the old Saxon term *lither*, or leather. There are various methods by which this change is brought about, and these we must briefly notice.

The hide or skin of an animal consists of the *epidermis* or *cuticle*, which is covered with hair or wool; below this is the *reticulated* or *net-like* tissue, and then comes the *dermis*, *cutis*, or true skin, which is next the flesh. The cutis is alone capable of forming leather; so that the other two must be got rid of before the manufacture of leather can be commenced. For this purpose, the hides or skins are put into a mixture of lime and water; and in the course of two or three weeks, the lime dissolves the hair-sheath, and combines with the fat of the hide to form an insoluble soap. The skins are then taken out and scraped upon a semi-cylindrical table, called the *beam* (fig. 255), with a curved two-handled iron scraper, called the *unhairing-knife*. The hair comes off readily, and leaves what is called the *grain* of the skin. A sharp *fleshing-knife* is then passed over the inner surface of the skin, to remove the flesh and the fat. In some cases, the skins are not put into lime-pits; but are hung up in a *smoke-house*, which is heated by means of a smouldering fire. Here the hides, under the influence of a hot steaming moist air, begin to ferment, and the hair becomes loose. This is called *sweating*. Steeping the skins in dilute acids has a similar effect. The stoutest kinds of skins are called *butts* and *backs*; the lighter ox hides are termed *hides*; while the lighter kinds of leather are made from *skins*. After the latter have been in the lime-pit, they are exposed to an alkaline solution, consisting of the dung of hens, pigeons, and other domestic birds, which renders them soft, and gets rid of the lime.

The true skin consists almost entirely of *gelatin* or *glue*: if this be put into a solution of certain vegetable substances, containing a chemical principle known as *tannin*, the skin will separate that substance from the liquid; and, by combining with it, form leather. This is what is done in the *tan-pits* (fig. 261). The hides are placed flat in these pits; and a quantity of powdered oak-bark (the most important tanning material in common use) being placed between them, water is let in, which forms a solution with the bark, called *ooze*. The skins are frequently turned, taken out and left to drain, or *handled*, as it is called, and placed in pits containing ooze, gradually increasing in strength; until, in the course of from nine to fifteen months for strong hides, the whole of the skin or dermis has disappeared, by the gradual combination of the gelatin and the tannin. When the tanning is complete, they are rinsed with water, and hung up in lofts to dry. Once or twice during the drying, the skin is placed on a cylindrical horse, and *struck* or smoothed with a triangular steel knife; the surface being occasionally sprinkled with a bunch of butchers' broom dipped in water. This brings what is called the *bloom* to the surface, and produces that peculiar colour which we see in new sole leather. The hides are next condensed under a weighted roller (fig. 256), and are then ready for the market.

The lighter hides or *kips*, and that description of leather used by the shoemaker, coach-maker, harness-maker, &c., are finished by the currier, who throws the skin over an upright wooden beam faced with *lignum vitæ* (fig. 257), and shaves it on the flesh side with a knife (fig. 258), the edge of which has been turned over at right angles to the broad blade. By this means, the skin is reduced in thickness, and the rough flesh side made tolerably smooth and even. The skin is then thrown into water, and, after soaking, is stretched upon a large table, and worked with a tool called a *stretching iron*. Lumps and inequalities in the leather are thus got rid of, and the skin is extended; both sides of the skin are smeared with a mixture of cod-oil and tallow, after which it is worked with a number of tools preparatory to laying on the *colour*, or blacking, which is a mixture of oil, lamp-black, and tallow. A black colour is also produced by applying to the skin a solution of sulphate of iron; which, uniting with the gallic acid of the tan, forms an ink dye. The immense demand for thin leathers, such as *white* and *dyed* leather for gloves, *morocco* for coach-lining, book-binding, pocket-books, &c., *roan* for slippers, &c., *skiver* for hat-lining, and *shamoy*, or wash leather, is supplied by various processes. White leather is not tanned, but *tawed*; or treated with a mixture of alum and salt in a large drum (fig. 264), and after having been washed and dried, the skins are returned to the drum, where they are churned with a paste of the finest wheat flour, and the yolks of eggs. This produces the glossy finish and softness of white kid, which is further developed by working it upon a rounded iron, mounted upon an upright beam (fig. 260).

Preparatory to tawing, &c., the skins must be freed from hair, wool, grease, &c.; and when thoroughly cleansed, they form what is called *pelt*. Sheep-skins, from which imitation morocco is prepared, are divided or split by means of a machine (fig, 266) which consists essentially of two rollers; the lower one solid, and the upper one composed of rings. These cylinders rotate slowly; and between them, but not in contact with them, is a knife which is made to move rapidly to and fro along the length of the cylinder. Standing on the opposite side of the knife, the man spreads out a skin on the lower roller, when it is dragged forward against the edge of the knife, and divided; one half going above, and the other below the blade. The rings which form the upper roller allow of adjustments depending on the varying thickness of the skin. Sheep-skins are sometimes split into three; the grain side being used for skiver, &c., the middle for parchment, and the flesh side for glue.

Goat-skins tanned with sumach, and dyed on the grain side, form the best morocco. Sumach consists of the powder of the leaves and young branches of shrubs growing in the south of Europe, and known as *Rhus cotinus*, *Venus sumach*, or the wild olive, &c. The pelts are made up into bags, and these, being filled with a solution of sumach, are placed in the *sumach-tub* (fig. 262), where they are agitated by a stirrer moving backwards and forwards. After about three hours, they are taken out, and piled on a shelf at the side of the vat; their mutual pressure causing the sumach to escape through the pores, and thus assist the tanning. After being treated with a stronger solution for about nine hours, the tanning is complete. When dry, they are finished by various processes, such as scraping and rubbing and oiling; the grained or ribbed appearance peculiar to morocco being given by rubbing the surface with a ball of box-wood furnished with ridges (fig. 263). The skins are dyed in the form of pelt, with a mordant of tin or alum, and cochineal for red, indigo for blue, orchil for purple, &c. *Dressing in oil*, or *shamoying*, consists in soaking the skin in water, and then rubbing oil or grease into its pores. As the water evaporates, the fat combines with the fibres of the skin, and converts it into leather. This process was originally applied to the skin of the chamois goat, and gave rise to the term *chamois* or *shamoy* leather. This kind of leather will bear washing, even when dyed, and is hence also called *wash leather*.

The demand for leather is large and constant: it forms an important part of our clothing, furnishes harness to horses, linings to carriages, covers to books, enters into the construction of various engines, machines, and articles of household furniture: so that we need not be surprised to find the manufacture in this country second in importance only to that of cotton and of wool, and about equal to that of iron. In the year 1859, the value of our exports in leather, including saddlery and harness amounted to 1,997,703*l.* sterling.

XVIII.—PARCHMENT.

Parchment must always be interesting for the many services which it has rendered to literature. Had it not been for the comparative indestructibility of this substance, the many wise and beautiful compositions of the ancients, which exerted so much influence in recovering Europe from the oppressive influences of the dark ages, could not have been preserved. Even when the rude hand of ignorance had erased the writing for the purpose of engrossing some superstitious legend on the parchment, it has still been possible to trace the marks of the original writing, beneath the monkish legend. In this way, valuable works apparently lost to the world have been recovered.

The skins of most animals are adapted to the making of parchment; but as most of them are more valuable for making leather, the sheepskin, so abundant in this country, is commonly employed by the parchment-maker. The skins of calves, kids, and dead-born lambs furnish the finer kind of parchment known as *vellum*. The skin of the ass, the calf, or the wolf furnishes the stout parchment used for drum-heads; ass's skin also supplies the parchment for battledores. The skins are unhaired either by sweating, or by steeping in lime, and this alkali also combines with the fat, which is thus got rid of in the form of an insoluble soap. After this cleansing operation, the skin is stretched upon a wooden frame, called a *herse*, in the manner shown in fig. 267, and a man called the *skinner*, furnished with what is called a *half-moon knife* (fig. 259), scrapes the skin so as to get rid of fleshy substances, dirt, and slime. The herse is then placed upon *tressels* (fig. 269), and the skin is sprinkled on the flesh side with powdered chalk or slaked lime, and well rubbed with a flat surface of pumice-stone; this is called *grinding*. The grain side of the skin is ground with pumice only. The knife is now passed over the skin, which produces a whitening effect, called *draining*. Fine chalk is next rubbed over both sides of the skin, which is then set aside to dry. The skin is next cut out of the frame, and a man, called the *parchment-maker*, stretches it upon a frame, called a *sumner*, and passes over the grain a sharp circular knife, paring off about half the substance of the skin, and leaving a smooth surface. Should any roughnesses appear, they are smoothed down with pumice, and the holes, if any, are closed by cutting the edges thin, and attaching small pieces of parchment with gum water. The green parchment used in bookbinding is coloured by means of verdigris. White of egg or gum-water is rubbed over to give the polish.

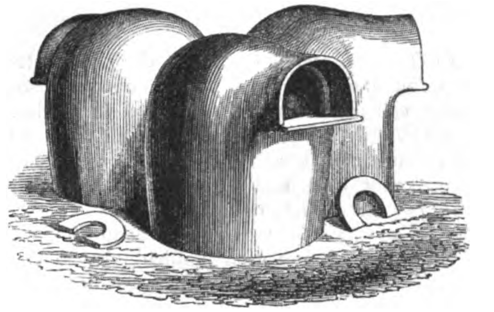
XIX.—GLUE.

Gelatin, the basis of portable soup, is made by boiling in water certain animal tissues and the waste residue of parts of animals which have served for food, together with the clippings of hides, hoofs, horns; feet of calves, cows, sheep, pigs; various membranes, and the waste particles in the carving and turning of ivory, &c. *Isinglass* is prepared from the membranes of different species of fish, especially of the sturgeon family. *Glue* is obtained from the same sources which furnish gelatin, assisted by the coarser refuse of the knacker's yard, the refuse from the skins of cats, dogs, &c.

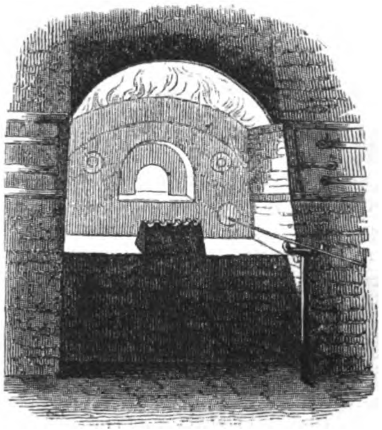
When the water in which these substances have been boiled is allowed to cool, it forms a tremulous jelly, called *size*. When the size is purified by means of sulphurous acid, and is dried in thin layers, it is used as a substitute for isinglass. Without such purification, the dried slices form glue.

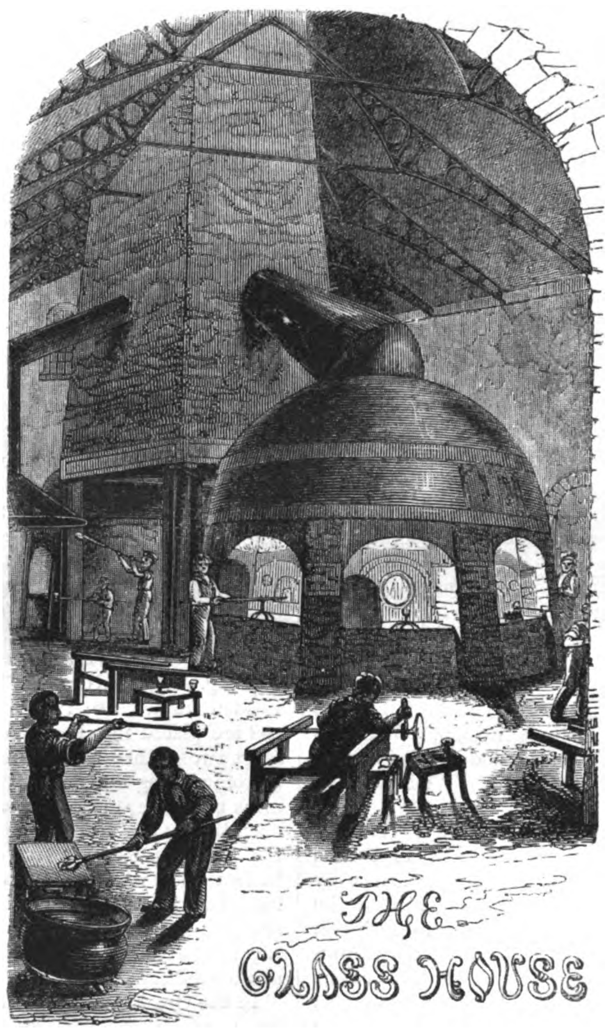
When the animal refuse arrives at the glue-maker's it is steeped in lime, washed in water, and placed on hurdles to dry. The glue-maker is not anxious to get rid of all the lime, since by exposure to the air it forms chalk, and he does not object to the presence of that substance in the glue. The boiling is carried on in a large iron cauldron; but the animal matters are not thrown into the water of the cauldron, or they would be liable to become attached to the sides and burn. A large rope bag or net is placed within the cauldron, and into this the animal matters are thrown: water is admitted, and is gradually raised to the boiling point; and as the clippings, &c, subside, fresh quantities are added, with occasional stirrings. A portion of the water is taken out from time to time; and when this cools into a clear jelly, the mouth of the bag is closed with cords, and the bag itself is wound up and made partly to coil round a beam (fig. 270), where it is left to drain. The contents of the bag are boiled a second and a third time in order to obtain size, and once more for the purpose of obtaining a weak solution for adding to a new bagful of animal matters; and when everything soluble has thus been boiled out, the contents of the bag are sent to the manufacturer of manures, who has risen into importance under the present improved and complicated system of agriculture. The solution of glue in the cauldron is run off into a *setting-back*, where it is clarified, and it is then admitted into long narrow wooden coolers: when cold, it is cut into square cakes, and the cakes into slices, by means of a brass wire (fig. 271), and the slices being placed upon nets, stretched in wooden frames, are removed to the *glue-maker's field* (fig. 272), and are placed in piles under a movable roof. The pile is taken apart two or three times a day, and the glue is turned to prevent it from sinking into the net, which, as it is, leaves its well-known mark upon the surface. The drying of glue is rather an uncertain operation in our variable climate. When about three-fourths of the moisture has evaporated, the drying is completed in lofts. Some weeks even or months may elapse before it is sufficiently hard for the market. During all this exposure to the air, the surface becomes dirty and mouldy. The glue is therefore *scoured* (fig. 268) with a scrubbing-brush and hot water, and lastly dried at a stove-heat.

In the Great Exhibition of 1851, large quantities of gelatin for ornamental purposes were shown in the French department, among which may be mentioned the thin white transparent sheets of *papier-glacé* or *ice-paper* for copying drawings: also dyed, silvered, or gilt gelatins for various purposes, among which was the making of artificial or fancy flowers. There were large groups of gelatin flowers, richly coloured, and closely imitative of nature; but the glittering, semi-transparent material gave them all a drenched appearance.


273. GLASS POTS.

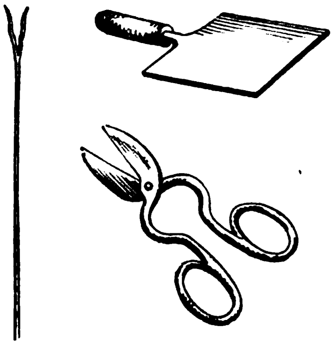

274. GLASS BLOWER AT WORK.

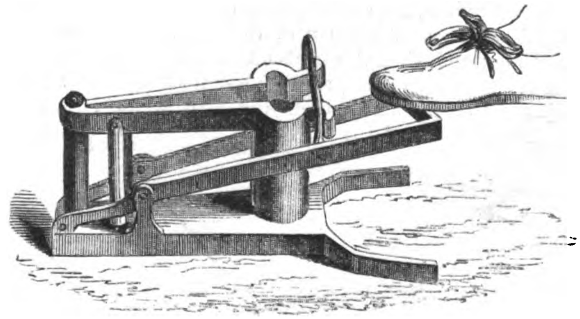

275. MOUTH OF THE FURNACE.

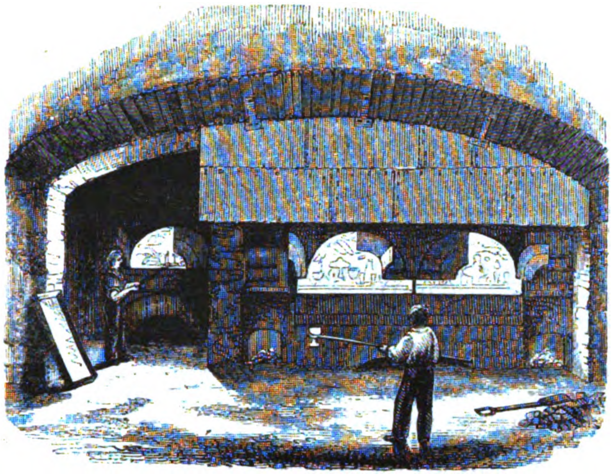


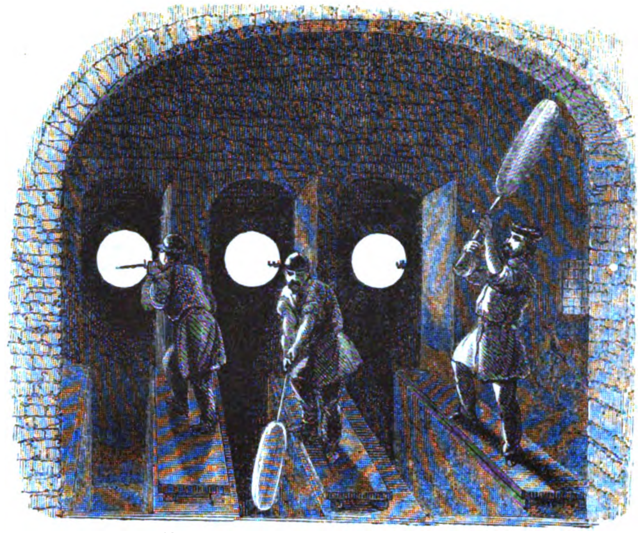
276.

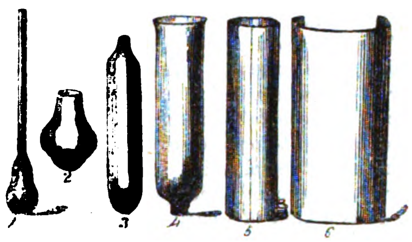

277. MAKING BOTTLES.

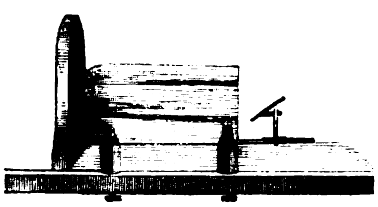

278. GLASS-BLOWER'S TOOLS.

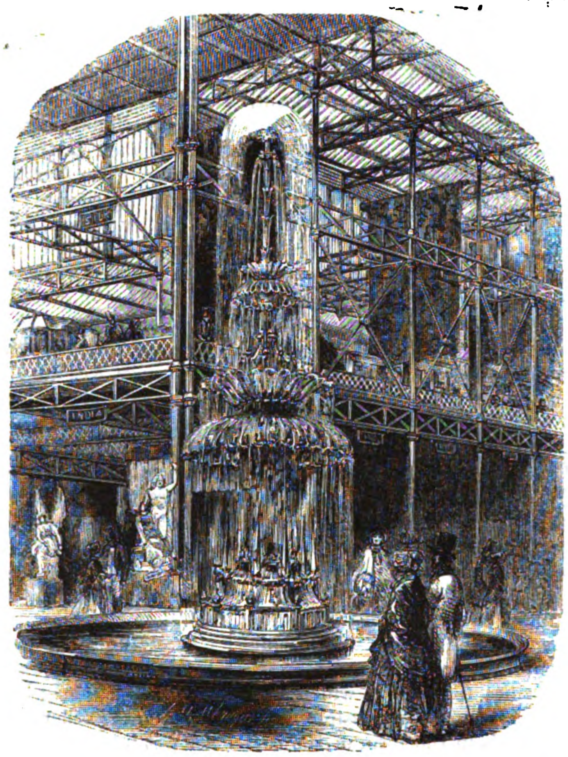

279. FLINT-GLASS BOTTLE MOULD.

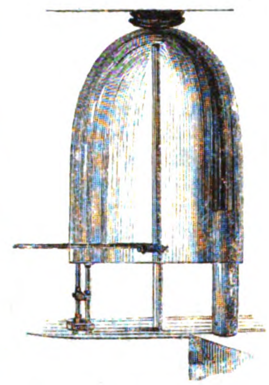

280. THE ANNEALING OVEN.

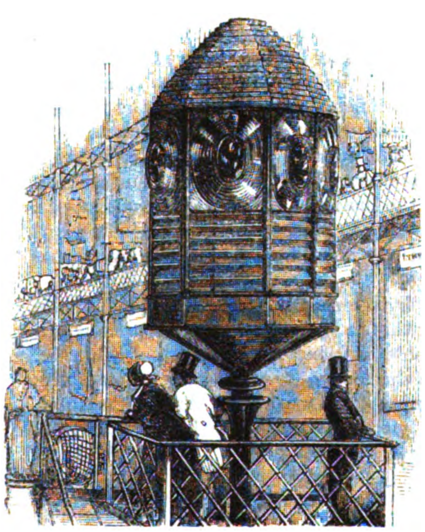

281. BLOWING AND SWINGING CYLINDER GLASS.


282 STAGES OF CYLINDER GLASS.


283. GLASS SHADE FRAME.


284. THE GLASS FOUNTAIN.


285. GLASS SHADE FRAME.


286. LIGHT HOUSE.


287. MASS OF ROCK CRYSTAL.


288. GLASS SHADES

K

XX.—GLASS.

In the eighth century, Wilfrid, Bishop of Worcester, substituted glass in the windows of his cathedral for the heavy wooden shutters, which were in common use, not only in his time, but for eight centuries later. The people gazed with astonishment on a substance which filtered the light from the wind and the rain; and were disposed to attribute the production of the transparent material to the powers of magic, rather than to the wit of man. And truly glass is a beautiful and a wonderful substance. Produced from materials which are themselves opaque, it can be moulded, blown, or worked into transparent vessels of large size, great strength, and beautiful form. A vessel of glass is the proper receptacle for that best of beverages, pure water, for in it the eye is at once satisfied of its purity. The numerous articles of glass in domestic use promote cleanliness and comfort; for nothing is so offensive to the eye as dirty glass. Even the mirrors which adorn our walls help us to preserve our persons in neatness and cleanliness. By means of glass the eye of age regains something of its youthful vigour: by means of glass the two extremes of the vast and the minute unfold their wonders in the telescope and the microscope: by means of glass the natural philosopher and the chemist have wrested innumerable secrets from nature: by means of glass the solitary lamp of a light-house marks out the distant horizon with its luminous fingers, and warns the navigator of rocks and shoals.

Glass is a compound of siliceous sand, with a mixture of an alkali and an earthy base, or with the oxide of one of the heavy metals, such as lead. The sand acts the part of an acid (silicic acid), and, by combination with the base, forms a class of compounds known as *silicates*. Thus *flint* or *crystal* glass is a silicate of potash and oxide of lead; *common window* or *English crown* glass, and *plate* glass, are a silicate of soda and lime, or a silicate of potash, soda, and lime; while coarse green *wine-bottle* glass is a silicate of soda, lime, alumina, and oxide of iron. The use of the lead is to impart brilliancy and fusibility to silicates, which, by themselves, would be fusible with difficulty. Lime and alumina confer hardness, and iron gives a dark colour. Potash and soda also assist the fusibility of glass.

Flint glass formerly obtained its silica from flints, which were calcined and ground. Fine sea sand, as free as possible from iron stains, is now used. The potash is in the form of the carbonate; and the lead in that of the red oxide. These materials being carefully mixed and sifted, form what is called the *batch* or *frit;* this is melted in pots of refractory clay (fig. 273), hooded over so as to protect the materials from the direct action of the enormous fire or furnace in which the pots are arranged in the form of a circle (fig. 276). The mouth of each pot projects from the furnace into the glass-house. The horse-shoe pieces shown in the figure are for contracting the mouth of the glass-pot when required (fig. 273). A flint glass-pot will contain about eighteen cwt. of melted glass.

Articles in flint glass are first formed by *blowing*, and they are afterwards worked into shape with the assistance of a few simple tools. The *blowing tube* is of iron, from four to five feet in length, with a bore of from one-third of an inch to an inch in diameter. The end of this, being heated nearly to redness, is introduced into the pot of glass or *metal*, as the workman calls it, a portion of which adheres to it; and the man, by turning it round, can gather up as much as he requires. He then rolls the glass upon a slab of cast iron, called the *marver*, in order to give it a regular exterior surface, and to produce a regular thickness when expanded by blowing. Applying his mouth to the tube, he distends the glass into a globular shape. When the size of the required vessel has been attained by blowing, a boy dips the end of a solid rod called a *ponty* into the glass-pot; and, gathering up a small quantity of the metal, attaches it to the blown glass, at a point exactly opposite the blowing iron. The latter is now detached by a drop or two of water, which chills and contracts the glass so as to allow the blowing iron to crack off. The workman now seats himself in his chair (fig. 274), rests the ponty on the two sloping arms, and rolls it backwards and forwards; so as to give a rotatory motion to the glass vessel, and proceeds to finish the neck; occasionally holding the vessel in the mouth of the furnace, so as to soften the glass when it has become too hard for working. The tools used are represented separately in fig. 278. The first is merely a fork for carrying the finished article to the annealing oven; the second is a flat surface of wood called a *battledore*, and is used for giving a flat surface to the bottom of vessels, such as wine-glasses, &c. There is also a pair of *shears* for cutting off superfluous metal, finishing the edges of tumblers, &c.; the glass, when at the proper temperature, being as easily cut as leather. The fourth tool, called the *pucellas*, resembles a pair of spring sugar-tongs: this tool is used to open or close the insides of hollow vessels, and to shape the vessel as it is rotated on the inclined planes of the chair, and for many other purposes. The fifth is called a *spring-tool;* it is a kind of tongs used for laying hold of half-formed handles, and for seizing the glass in certain positions. The glass-blower has also a pair of *compasses*, and a *measure-stick*. When the vessel is brought to shape, handles, feet, rings, &c., are attached by welding by contact, which is one of the valuable properties of glass at about a red heat. The various operations of the glass-house are represented in fig. 276. Bottles are made in a mould (fig. 279), consisting of two parts, which fall open, except when pressed together by placing the foot on the treadle. In blowing a bottle, the man gathers up a sufficient quantity of glass upon his blowing iron, inserts the glass into the open mould, presses the two parts together with his foot (fig. 277), and, by blowing, causes the glass to swell out and line the interior surface of the mould.

When glass is rapidly cooled, it becomes so brittle that it is entirely unfit for use. This inconvenient property is removed by the process of *annealing*, or slow cooling. The annealing oven (fig. 280) is a long low arch, hot at one end and gradually cooling towards the other end. As the articles of glass are finished, they are put into iron trays at the hot end of the arch; and, as these become full, they are pushed forward by other trays, until, after many hours, they arrive at the cool end of the arch, and are fit for use.

Flint glass vessels are ornamented by the glass-cutter, who grinds away portions of the glass, by means of an iron wheel, constantly supplied with sand and water. The rough sand-marks are smoothed out by a stone-wheel with water; and the cutting is finished on wooden wheels with rotten stone, putty-powder, &c. The ornamentation of glass is, for the most part, a mistake in art; the material is so pure, the best forms are so simple, and the surface is so exquisitely finished by the heat of the furnace, that the attempt to superadd ornaments usually detracts from these valuable qualities. The idea of the glass-cutter is to increase the brilliancy of the material by forming the surface into facets, and thus rivalling the lustre of gems and precious stones. There may be some advantage in this, if done judiciously; but one of the chief faults of our workshops is that of over-ornamentation.

Crown glass is formed by blowing a globe at the end of the blowing-iron, transferring this to the ponty; and by causing the globe to rotate on a horizontal axis before the mouth of a furnace, it flies open into a large sheet or *table* with a noise something like that produced by opening a wet umbrella. Another method, known as the *cylindrical process*, is represented in fig. 281. A

quantity of metal being collected at the end of a blowing-iron, as in No. 1, fig. 282, is blown into the form No. 2, which is elongated by centrifugal force into the form No. 3. The man then forces an additional quantity of air into this elongated vessel, and, applying his thumb to the end of the tube, holds the glass in the furnace as represented in fig. 281, when the imprisoned air, expanding under the heat, bursts open the end or thinnest portion of the glass. The uneven edge is trimmed with scissors, and enlarged with the pucellas, until it is brought to the shape No. 4, fig. 282. The neck is removed by turning a red-hot iron round the part, and allowing a little water to fall on the heated glass. Water is also passed down the length of the cylinder so as to crack it preparatory to opening it; and it is now in the condition of No. 5, after which it is taken to a furnace, placed on what is called a *flatting hearth*, where it is opened, and spread out into flat sheets of glass. The magnificent glass shades represented in fig. 288, some of which are five feet and upwards in height, were formed by this process. If these large shades are to be preserved as such, each one is placed in a *frame* (figs. 283, 285), where, being supported in the one case horizontally, and in the other vertically, a mounted diamond is made to act against the side, by which means the glass can be reduced to shape, and to the proper proportions.

Plate-glass is formed by collecting a quantity of the molten metal in a glass-pot or cistern, and swinging it by means of a crane over a metal table, furnished at the sides with ribs of metal to prevent the glass from flowing off, and also with a roller for rolling it out flat. The cistern is tilted over, and a torrent of melted glass is poured upon the table, producing a very fine effect; when rolled out into a sheet of uniform breadth and thickness, it is pushed off the casting-table upon a wooden platform, and so conveyed to the annealing oven, where it remains flat on the floor for about five days. After this, the plate undergoes a laborious system of grinding and polishing before it is fit for silvering.

The application of lenses to light-houses (fig. 286) is an improvement on the old system of Argand lamps and metallic reflectors. In this arrangement there is a single central lamp consisting of four concentric wicks, furnishing a large volume of flame. Around this central lamp lenses are arranged so as to form an octagonal hollow prism, which, revolving about the fixed central flame, gives to a distant observer successive flashes or blazes of light, whenever one of the octagonal faces crosses a line joining his eye and the lamp. The difficulty of making these large lenses sufficiently accurate in form in one piece, led to the suggestion of building up a lens in separate pieces, the result of which has been quite successful.

Far more difficult is the manufacture of glass for optical purposes; and the difficulties increase with the size; so much so, that the production of the large object-glass of a telescope free from little specks and inequalities known as *striæ*, *wreaths*, *knots*, *threads*, and *tears*, and imperfections arising from want of uniform density in the glass, is all but impossible. The maker of an object-glass eleven or twelve inches in diameter, recently offered it to the Royal Observatory at Greenwich, for the sum of 1,100 guineas, and the price would gladly have been paid, had the glass been free from defect. We have not succeeded in producing glass of the pellucid clearness of Nature's workmanship, as in the mass of rock-crystal, fig. 287; and we are only conscious of our defects when we come to examine her works, and find it necessary to employ that perfection which she commands in producing them. The glass fountain of the Crystal Palace, fig. 284, may sparkle in the sunshine and cast its rainbow tints around; but such a work is rude and clumsy in the extreme when compared with the exquisite instruments which, while they imitate, vastly extend the powers of that most exquisite of organic structures, the human eye. Some years ago M. Guinand, a clock-maker of Brenets, near Neufchâtel, in Switzerland, succeeded in making disks of flint-glass six inches in diameter, of great purity. He kept his method secret, and only imparted it to his sons on his death bed. They have since shared it with other persons, and the effect has certainly been to improve the manufacture of optical glass.

Our exports in glass during the year 1859 were as follows:—

	Cwts.	*Declared value.*
Flint-glass	59,007	£179,349
Window-glass	27,686	39,795
Common bottles	622,642	327,301
Plate-glass		61,133
		607,578

289. GREEK VASE.

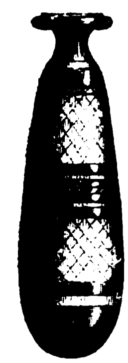
290. INTERIOR OF A TUMULUS NEAR RADEBERG.

291 ROMAN VASE, FOUND AT ZAHLBACH.

292. INDIAN BLACK POTTERY.

293. VASE FOUND NEAR DIEPPE.

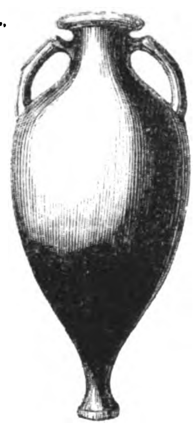
294. ARRANGEMENT OF VESSELS IN A TOMB NEAR CASTEL, IN THE DUCHY OF NASSAU.



295. PURSE-SHAPED VASE, RED AND BLACK.

296. DECORATED URN, FOUND AT COLNEY IN NORFOLK.

297. RED AND BLACK VASE.

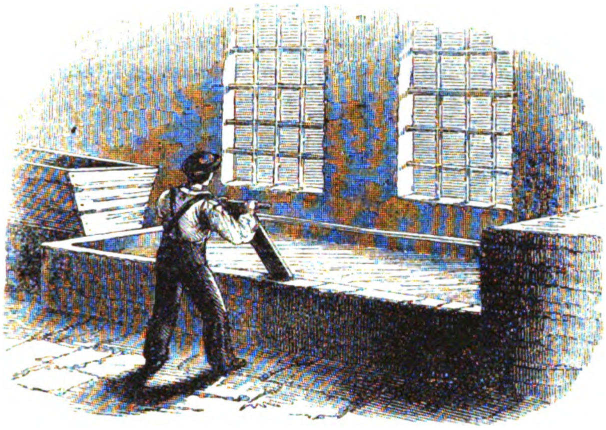


298. ROMAN AMPHORA, DUG UP NEAR LONDON BRIDGE.

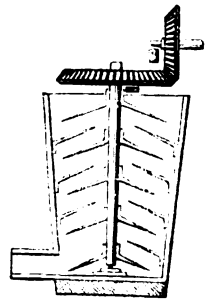
299. VASE FOUND AMONG THE RUINS OF ANTINOE.

300. TUNISIAN POTTERY.

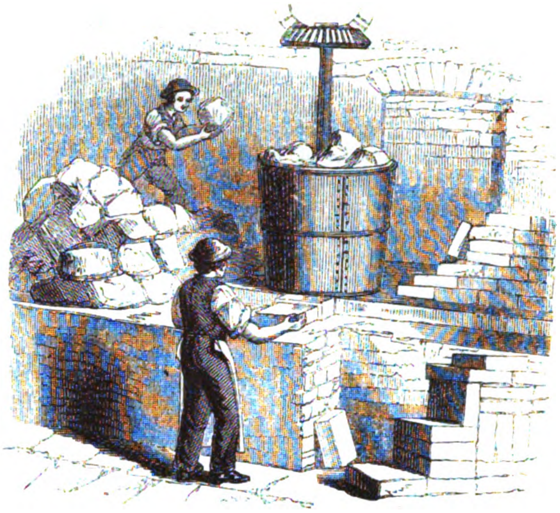
301. ANCIENT URN, FOUND NEAR NORWICH.



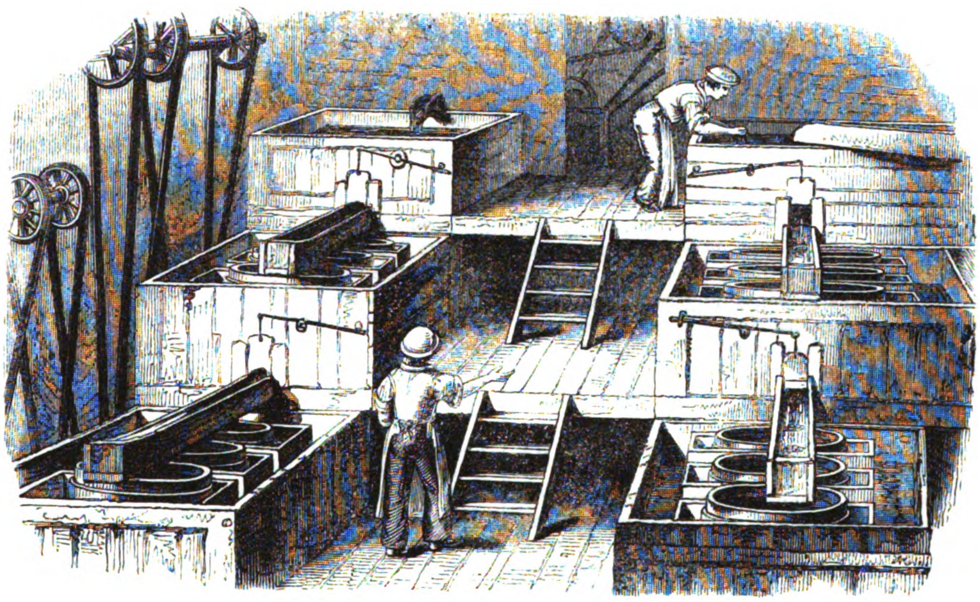
302. BLUNGING.



303. PUG-MILL.

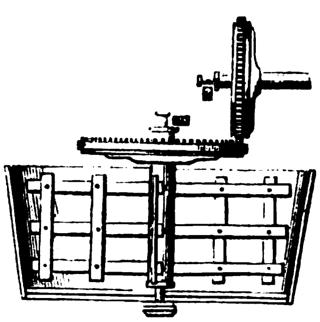


304. GRINDING THE CLAY.

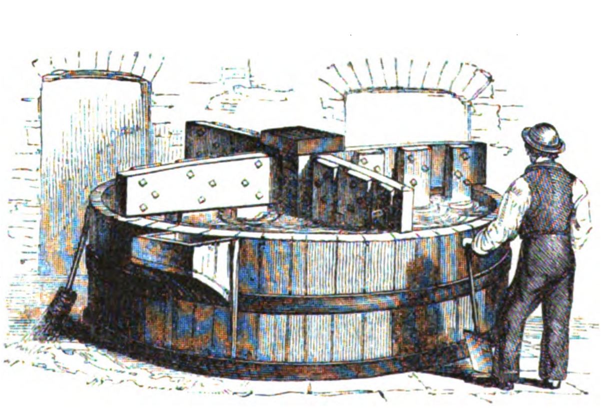


305 MIXING THE INGREDIENTS.

306. FLINT MILL.



307. SECTION OF FLINT PAN.



308. FLINT PAN.

XXI.—POTTERY AND PORCELAIN.

As in digging into the earth we may sometimes turn up the fossil remains of animals and plants which illustrate a former condition of the surface of the globe, so we may also turn up urns and utensils of baked earth which throw light on the condition of its ancient inhabitants, whom the historian has neglected to notice, or has passed lightly by. It is curious that a piece of common pottery ware, which a slight blow might shiver to pieces, should be far more enduring than epitaphs in brass and effigies in bronze; that the mound of earth erected to the forgotten warrior or chieftain should be more enduring than the deeds of kings, pictured on the walls of stately palaces. Monuments of brass and of iron rust away; silver and gold tempt the cupidity of the thief; stone crumbles under the disintegrating effects of the atmosphere; ink fades, and paper decays; but the fictile vase deposited in some quiet receptacle survives the changes of history and of chemistry, and even in its fragments preserves some traces of the hand that moulded it. Fig. 290 represents the interior of one of the green mounds or tumuli so common in the north of Germany, and the kind of vessels found therein. The latter probably contained the ashes of the dead, as no skeleton or bones were found in them; but in many cases the skeleton still remains, with vases at the feet and head, or hanging on pegs from the sides of the tomb. Fig. 294 shows one form of arrangement of vases in a tomb where the body had been burnt, and the ashes deposited in a central urn surrounded by other vessels, the four smaller ones being inclined towards the larger one in the centre; the other vessels were of glass or of pottery, and had contained such liquids as wine, milk, balm, oil, &c. Excavations among the ruins of ancient cities have led to the discovery of innumerable clay records of early nations. Thus Layard discovered a whole library in the palace of Sennacherib, containing histories, deeds, almanacs, spelling-books, vocabularies, inventories, horoscopes, receipts, letters, &c. Altogether about 20,000 of these clay books of the Assyrians have been discovered; and on the impressions of seals on some of the royal muniments may still be traced the marks of fingers, made while the clay was yet moist.

The word pottery is derived from the Lower Latin word *potum*, a drinking-vessel; and the earliest employment of earthen vessels was doubtless for domestic use. Many of those dug up in this country are of Roman workmanship, such as the fusiform *amphora* (fig. 298); others owe their origin to a period anterior to the Roman invasion, such as the urn (fig. 301), made of a thick black clay, ornamented with some tool, but evidently not turned: this, together with fig. 296, contained bones, ashes, and charcoal. Roman pottery is distinguished by the greater care in the workmanship and the superiority of the material; the elegant vase, fig. 293, is of this kind, while fig. 291 shows the method of ornamenting in a different coloured clay, such as a flowering branch in white clay on a vessel of the ordinary red pottery. In this respect Greek pottery is pre-eminent, as in fig. 289, in which the figures are red on a black ground. Fig. 299 is a specimen of ancient Egyptian pottery, unglazed; and fig. 292, which represents a specimen of Indian black pottery, shows that, as in our own day, a liquid glaze was employed, the specimen proving that a portion of it originally flowed down the unglazed side of the vessel. Many of these ancient forms are perpetuated by Eastern nations at the present day, as will be seen by reference to the ware from Tunis, fig. 300.

Porcelain is only a superior kind of pottery; but it is distinguished by being translucent, while every form of pottery is opaque. The origin of the word porcelain is uncertain: some refer it to *porcellana*, the Portuguese for a drinking-cup; others to the same word in Italian, which signifies a univalve shell of the genus *Cypriœdæ*, or cowries, having a high-arched back like that of a hog (*porco* in Italian), and a white, smooth, vitreous glossiness of surface.

Pottery is divided into two classes, the *soft* and the *hard*—terms which have reference to the composition of the ware and the temperature at which it is baked; thus, common bricks, earthenware, such as pipkins, pans, &c., are soft; while fire-brick, and crockery, such as Queen's ware, stone-ware, &c., are hard.

The essential ingredients in every article of pottery and of porcelain are silica and alumina, or flint and clay. The pure silicate of alumina is an ideal type not attained even in the finest porcelain, while in the coarser varieties such impurities as iron, lime, potash, &c., are not much regarded, although they give character to the wares. In some cases it is necessary to add to the compound of silica and alumina certain substances for rendering those refractory materials more fusible. Soft pottery is composed of silica, alumina, and lime; it is usually fusible at the heat at which porcelain is baked, and can be scratched with a knife or a file. Stone-ware is a kind of coarse porcelain, and is composed of silica, alumina, and baryta. Hard porcelain contains more alumina and less silica than the soft; it is fired at a higher temperature, and is more dense. Soft porcelain contains more silica and alkaline fluxes than the hard; it can be readily scratched with a knife, and cannot resist a very high temperature.

Glazes form an important part of fictile ware. When the article has been properly shaped, and passed once through the fire, it forms a hard porous substance, named *biscuit*. *Glazing* or *glassing*, consists in covering the ware with a thin layer of glass, which deprives it of its porosity. In the translucent wares, such as fine porcelain, the glaze must resemble in character the body of the ware, only it must fuse at a lower temperature.

In such a case, the biscuit being white, the glaze must be so also; whereas in pottery-ware the paste is contaminated with protoxide of iron, which, under the oxidizing influence of heat, becomes converted into the red peroxide, the result of which is a red biscuit, which has to be concealed by opaque or coloured glazes. These do not, as in the case of fine porcelain, form part of the ware itself, but constitute a distinct layer on its surface. It will be understood, then, that in the case of porcelain and fine pottery the wares pass twice through the kiln: in the first firing they are converted into biscuit; they are then coated with their ornaments, and covered with glaze, which on the second firing become vitrified. Coarse pottery, however, is not sufficiently valuable to admit of two firings. The glaze is therefore added while the ware is still in the kiln, at a high temperature. For this purpose moist salt is thrown into the kiln, and becoming volatilized and decomposed in the presence of moisture and of hot clay, hydrochloric acid is disengaged, the silica of the ware unites with the soda of the salt, and this, combining with the silicate of the alumina, forms a fusible double alkaline silicate or glaze on the surface of the articles.

The clays used in the Staffordshire potteries are obtained from Devonshire and Dorsetshire, the latter furnishing *brown* and *blue* clays, and the former *black* and *cracking* clays. The black clay contains a little bitumen or coaly matter, which disappears in the kiln and produces a nearly white biscuit. Cracking clay is liable to crack during the first burning, but its white colour renders it valuable for mixing with other clays. Brown clay is liable to the objection of *crazing* or cracking of the glaze, from the unequal expansion between the glaze and the body of the ware. For ordinary purposes blue clay is in great request; but for the finer kinds of earthenware the *China clay*, or *kaolin*, of Cornwall, consisting of felspar in a partially decomposed state, is much employed. It is a white, impalpable powder, containing 60 parts of alumina, and 20 of silica.

The silica used for mixing with the clays is obtained from the flints of the chalk district. The mineral *Pegmatite* contains all the materials for hard porcelain ready mixed.

The preparation of the materials involves a number of processes, and much care and judgment on the part of the manufacturer. The different kinds of clay, such as blue and white, being mixed in the proper proportions, are worked together with water by means of a long wooden blade, called a *blunger* or *plunger*, and the operation is called *blunging* (fig. 302). To assist the blunging, the clay is sometimes passed through a *pug-mill* (fig. 303), consisting of a cast-iron cylinder, lined with knives, and furnished with an upright shaft in the centre, also furnished with a spiral line of knives. These knives act like shears, and cut the clay, as it passes from the top downwards (fig. 304), into small pieces, which are forced out through an opening at the bottom of the cylinder, whence it is removed to a vat for the blunging.

The flints are prepared by calcining in a kiln, quenching in water to increase their brittleness, and reducing them to fragments by means of the stampers, fig. 306. These fragments are reduced to powder in a *flint-pan*, figs. 307, 308, consisting of a circular vat, the bottom of which is formed of felspar, and containing in the centre an upright shaft with four projecting arms or frames, by which motion is given to the *runners*. These are large siliceous stones called *chert*, and serve to grind the flints to powder by their lower surfaces crushing the flints against the bottom of the vat. In the course of some hours the flints are reduced to powder, which, mixing with the water of the vat, forms a creamy mixture. The flint-powder is considered fit to mix with the clay when a wine pint of it weighs 32 oz., an equal bulk of the diluted clay weighing 24 oz. These two ingredients are mixed by agitation, and passed through sieves of hard-spun silk, arranged on different levels, as shown in fig. 305, so as to allow the mixture to pass from coarser to finer sieves, the straining being assisted by a *jigging* motion given to the sieves. The mixture is now called *slip*, and has next to be brought to the proper degree of thickness required by the potter. For this purpose it is boiled in a *slip-kiln* (fig. 309); it consists of a long brick trough, with flues under it for heating the mixture: it is kept constantly agitated to prevent the heavier flint from settling, and when a sufficient quantity of water has been evaporated, the mixture is taken out and subjected to the process of *wedging*. This consists in cutting up the mass in the slip-kiln into wedges, and dashing them against each other, so as to get rid of air-bubbles, which would otherwise form blisters in the ware. This wedging is carried on at intervals during several months, and during this *ageing* of the paste a fermentation takes place; gases are given off, and the paste improves in texture and in colour. When the paste is about to be used, it is passed through the process of *slapping*, in which a man takes up a mass of 60 or 70 lbs. weight and dashes it down on the bench before him, dividing it frequently by drawing a wire through it and dashing down one fragment upon the other, taking care to preserve the *grain* of the paste, that is, to slap the layers parallel to each other, and not at an angle; for if this were not attended to, the ware would be liable to fall to pieces in the baking.

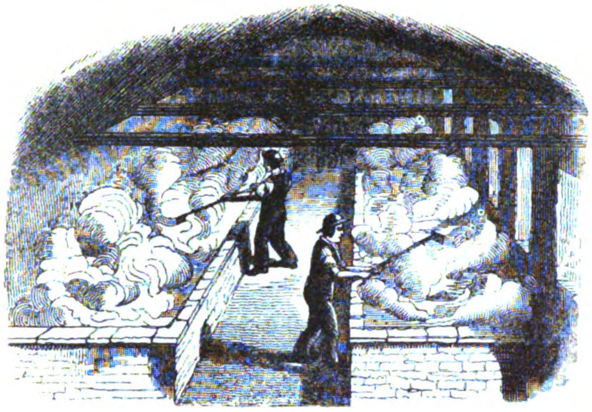
The first process in the manufacture of earthenware vessels is *throwing*. It is performed by means of the *potter's wheel* or *lathe*, fig. 310, which consists of an upright shaft with a disk of wood at the top, and a grooved pulley at the bottom, over which passes a band from a wheel, the revolution of which imparts the required degree of speed to the shaft and its top-board. The paste, as furnished by the slapper, is weighed out into portions of the proper dimensions for the required article, and rolled up into balls; the thrower, seated at his work, as shown in fig. 310, dashes one of these balls upon the centre of the revolving board, and with both hands squeezes up the clay into a conical form, and again forces it down into a mass in order to give it solidity. With one hand, or with the finger and thumb, in the mass he gives the first rude form to the vessel; and then with a piece of horn called a *rib*, which has the profile of the shape of the vessel, he smooths the inner surface, the attendant meanwhile moving the wheel at different rates of speed, according to the direction of the thrower. In order to give the vessels the same height, the thrower has before him a simple gauge, the point of which marks the height of the intended vessel. It is obvious, from the nature of the process, that the thrower can only produce circular vessels, such as basins and tea-cups: the ornaments, handles, spouts and lips are added by an after process. As soon as one vessel is complete, it is cut off at the base by passing under it a fine brass wire, and the thrower proceeds to work another ball. The process of throwing may be further illustrated by means of figs. 311, 312. In order to form the lower part of the vase D, fig. 312, the thrower dashes upon his wheel the lump of clay A, fig. 311. This is worked into the conical mass B; then into the rude cup C, and lastly into D. The portion E, of fig. 312, is represented on the wheel at E, fig. 311. It will be observed that in all the figures on the wheel a spiral grain is given to the clay, which is best adapted to retain the form of the plastic material. There is always a tendency to distortion during the baking, which may be estimated by drawing a vertical line, or two points in the same vertical, upon the soft clay vessel: it will be found after the firing that these two points are no longer in the same vertical; the lower point will have moved more towards the right than the other; a fact so well known to the workmen, that in sticking on handles to vessels, they place them somewhat askew, and the distortion produced by the contraction in firing, restores them to their erect position.

It will be observed that the members D, E, fig. 311, are much thicker than the corresponding parts in fig. 312. They cannot be produced sufficiently thin in the operation of throwing, but have to be reduced by being put into a turning-lathe and worked with cutting-tools just in the same manner as articles in wood, ivory, and metal. In this way the outer surfaces of cups, &c., acquire that finish and polish, together with rings and other ornaments capable of being produced by turning. By the process known as *engine-turning*, variety is given to the rim, and various kinds of indentations are produced.

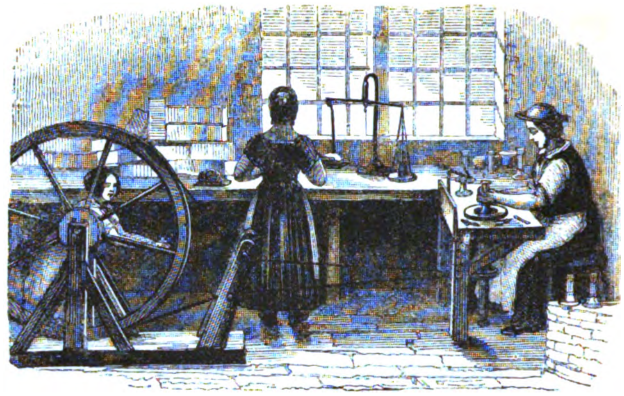
The articles are still in the *green state*, as it is called, and handles, spouts, and other additions are attached to them by means of slip. The paste for the handles is first formed into a long cylinder or other form, by forcing it through a metal tube at a small press, and then cutting it up into lengths and bending them to the required shape. Ornamental handles, &c., may be formed by pressing the paste into plaster of Paris or steel moulds (fig. 316).

The second method of forming articles in earthenware is by *pressing*, which is the same operation on a larger scale as the method just noticed of forming ornaments in plaster moulds. Plates and dishes are made by this method. Deep vessels, such as ewers, vases, &c., are formed in moulds generally made in four parts, fitting accurately together. The paste is rolled out much in the same way as in preparing the crust of a pie; and each section of the mould being carefully lined with it, the edges are trimmed and moistened with slip, and the parts of the mould are carefully brought together and secured by a strap. The presser then passes his finger up each joint so as to form a channel into which a thin roll of clay is inserted. This is worked in, first by the finger and thumb, and then smoothed with moist leather. Fig. 319 shows the presser at work, while figs. 313, 314, and 317 show the moulds or portions thereof. The mould is placed in a warm room, and when sufficiently dry is taken to pieces, and the article is removed to be *fettled* or trimmed with proper tools, to get rid of the appearance of seams and to remove superfluous portions of clay. The article is then cleaned and polished with a moist sponge, the handles and other appendages are added, and lastly it is polished with horn, and is set aside to dry previous to baking.

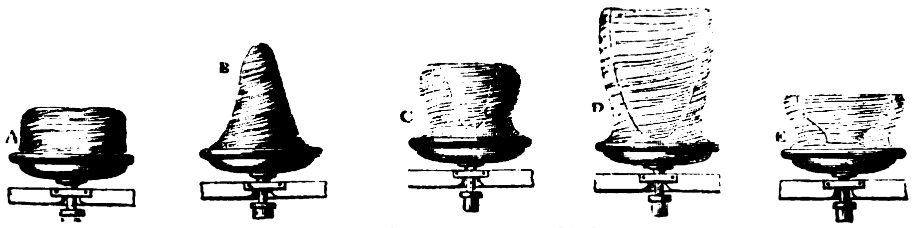
There is yet another method of forming articles in earthenware, namely, by *casting*. The paste being mixed with water, is



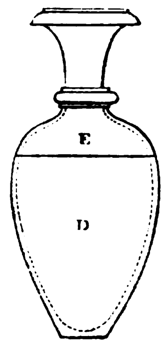
309. SLIP-KILNS.



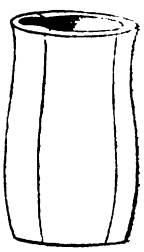
310. THROWING.



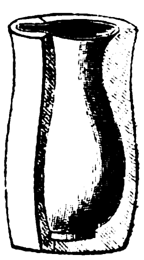
311. PROGRESSIVE STAGES OF THROWING.



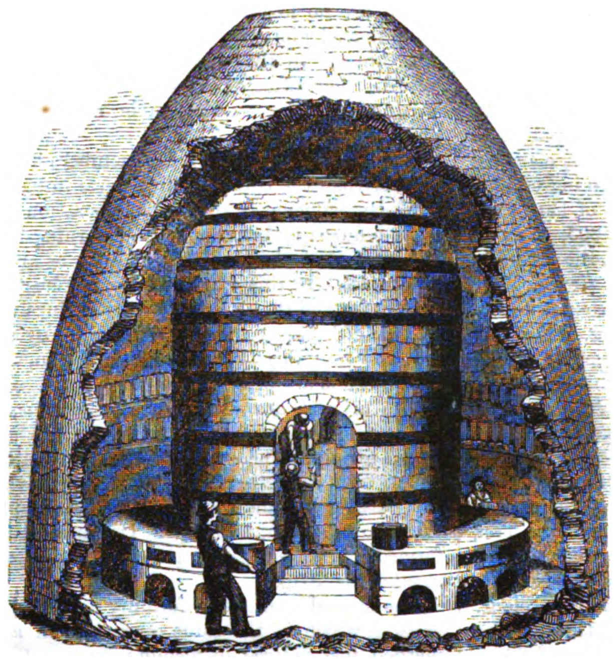
312. VASE.



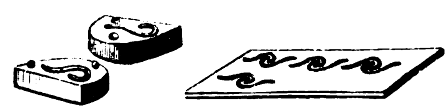
313. MOULD.



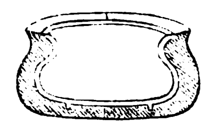
314. MOULD.



315. BISCUIT KILN.



316. MOULD FOR HANDLES.

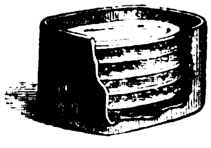


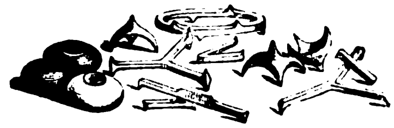
317. MOULD.

318. UNGLAZED POTTERY FROM TUNIS.

319. HOLLOW WARE PRESSING.

320. PRINTING STONE WARE.

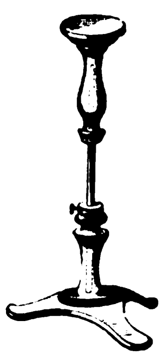

321. SEGGAR.

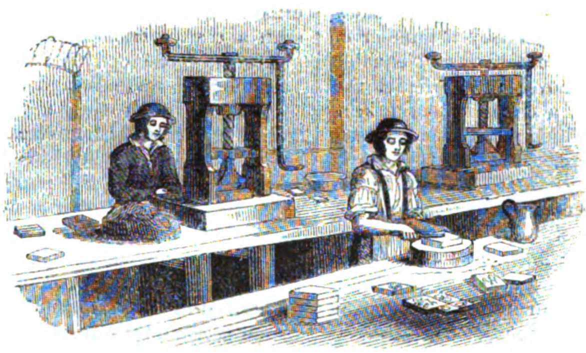

322. WATCHES, COCKSPURS, TRIANGLES, AND STILTS

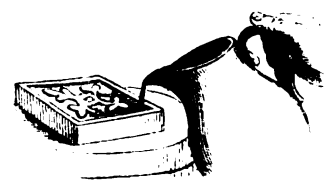

323. PAINTING PORCELAIN.

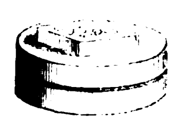

324. SÈVRES PORCELAIN.


325. BURNISHING.


326. WHIRLER.


327. PRESSING AND SCRAPING TILES.


328. FILLING.


329. WHIRLER.


330. ENCAUSTIC TILE.
(*Yellow on blue ground.*)


331. WEDGWOOD'S FACTORY AT ETRURIA, IN STAFFORDSHIRE.


332. ENCAUSTIC TILE.
(*White on black ground.*)

poured into a mould, the plaster of which quickly absorbs a sufficient portion of the water of the mixture, to leave on its walls a thin lining of the paste thus suddenly removed from solution. The fluid portion in the mould is next quickly poured off; and when the delicate lining is sufficiently dry, the mould is again filled with the fluid mixture, and again quickly emptied. The mould is then placed in a stove, and when dry it is taken to pieces, and the object removed. Statuettes and other articles are formed in this way.

The processes above described apply to porcelain paste as well as to pottery; so that we may now pass on to the process of *firing*. The articles in the green state are kept in a heated room until they have parted with much of their moisture. When sufficiently dry, they are placed in coarse strong vessels of marl, called *seggars*, for the purpose of protecting them from the direct action of the fire and the products of combustion. Most of the seggars are oval in shape (fig. 321), but those used for plates are cylindrical. The articles are prevented from touching each other by placing between them sand or powdered flint, and in some cases rings of earthenware are placed in saucers, cups, &c., to preserve their shape. As the seggars are filled, they are conveyed to the kiln (fig. 315), and are piled up so that the flat bottom of one seggar may serve as a cover to the one above it: a roll of clay is placed on the rim of each seggar, for the one above it to stand on. Each pile of seggars is called a *bung*. About 30,000 pieces of ware may be included in one baking.

The kiln (fig. 315) is surrounded by an outer cone or *hovel* of brickwork, a portion of which is removed in the engraving to show the interior arrangements. The kiln itself is a domed cylinder of brickwork bound with iron bands, and with a hole in the top immediately under the chimney of the hovel to allow the smoke to escape. The kiln is surrounded by a number of fires and flues, arranged so as to produce a high and equable temperature within. The use of the hovel is to protect the kiln from the weather, and to furnish a chimney to the kiln. It is furnished with shelves inside, on which newly-made seggars are arranged for drying previous to baking. When the kiln is filled, the doorway is bricked up, the fires are lighted, and in the course of three or four hours flame is seen to ascend through the cylinder into the chimney of the hovel. After about ten or twelve hours, the fireman takes out his first *watch* to see how the baking goes on. *Watches*, or *trial-pieces*, are rings of fire-clay which assume different shades of colour at different temperatures. A number of these are placed in a seggar opposite to a hole in the cylinder, and the fireman, removing the clay stopple from this hole, inserts a long iron rod, and withdraws a watch. When it is cold, he is able to judge by its colour of the heat of the kiln, and to regulate it accordingly. During the next twenty or thirty hours he frequently draws out a watch, and when he deems the baking to have been sufficient, the fires are allowed to go out, and the kiln is left to cool during twenty-four or thirty hours. About fourteen tons of coal may be consumed in one baking.

The ware is now in the state called *biscuit:* not because it has been twice cooked or baked, but because it resembles the dry and rough surface of well-baked ship bread. Some articles, such as wine-coolers, butter-coolers, and water-bottles, are finished in the state of biscuit. It is in the condition of the unglazed pottery-ware of Tunis (fig. 318). Water contained in these vessels, slowly oozes through the ware, and forms a dew on the outside, the evaporation of which carries off so much heat as to lower the temperature of the remaining liquid many degrees below that of the air.

When the ware is removed from the seggars, it is carefully examined. White and cream-coloured wares require only a coating of glaze to fit them for the market. Patterns are added in the state of biscuit by a transfer process now to be described. For example, the blue of the common dinner-service is produced by means of oxide of cobalt, ground flints and sulphate of baryta, fused or fritted together, reduced to powder, mixed with a flux of ground flint and thick glass powder, and then mixed with boiled linseed oil: this forms a viscid kind of printers' or engravers' ink, and with this the lines of the pattern engraved upon copper plates are filled in. A wet sheet of thin yellow unsized paper is now placed upon the copper plate, and with it passed through a cylinder press: the paper receives the impression from the plate, and a little girl called the *cutter* cuts the pattern into its separate parts, rejecting the white unprinted portions, and hands them to a woman called the *transferrer* (fig. 320), who places the several sections of the pattern, with the ink part downwards, in their proper places, upon an article in biscuit-ware, and by rubbing the paper with a roll of flannel, transfers the ink from the paper to the porous biscuit. On placing the articles in water, the paper separates, leaving the pattern on the ware. The article is next dipped into glaze, which, when dry, gives it a white porous chalky appearance, completely concealing the pattern; but on passing the article a second time through a kiln, at a much lower temperature than before, the white powder fuses into a transparent glass, through which the pattern is visible; while at the same time, it deprives the biscuit of its porous character, improves its appearance, and renders it fit for use.

Glazes usually contain flint and an alkali, the common ingredients of glass, and often a portion of lead, tin, or borax, to render them more fusible. They may be *transparent*, *opaque*, or *coloured*. If the paste be white, or of a tint pleasant to the eye, a transparent glaze will improve its appearance. A clay possessing good plastic qualities, but a bad colour, may be dipped into a slip made of a superior kind of clay and in this way become veneered on the inside with a pure white paste; it may also be ornamented on the outside with variously coloured pastes: in such a case, a transparent glaze would be proper. When the glazes are made opaque by means of oxide of tin, &c., they become true enamels, and effectually conceal the body of the ware which they cover. Colour is given to glazes by the addition of various metallic oxides.

The glazes are applied by reducing them to fine powder, mixing them up with water, and plunging the biscuit-ware into the mixture: if this be skilfully done, the porous ware will be completely covered with glaze in fine powder, except at the points where the article was held, and these are afterwards coated by means of a camel's hair brush dipped in the powder. The glaze thus applied is vitrified in the *glaze* or *gloss* oven. In arranging the articles in the seggars, they are prevented from touching each other by being made to rest on supports of various forms, and known as *cockspurs*, *triangles*, *stilts*, &c. (fig. 322.) The method of arranging flat pieces in the seggar is shown in fig. 321. The seggars are piled up in the glaze-kiln as in the biscuit-kiln; the temperature is raised sufficiently to fuse the glaze, an effect which is judged of by covering watches with glaze (fig. 322), which, being drawn out from time to time, serve to guide the workman.

The ornamentation of porcelain belongs rather to the fine arts than the useful arts. Porcelain may indeed aspire to the dignity of having created schools of art, which have had their rise, their prosperous days, and their fall, their great masters, and their imitators. In their admirers the love of china-ware often amounts to a passion, for they do not even now hesitate to give 200 guineas for a single plate, a similar sum for a cup and saucer, and 1000 pounds for a single vase, provided they are satisfied that such articles represent the best days of Sèvres or of Dresden, of Chelsea or of Capo di Monti, &c. The famous *Majolica*, or enamelled ware of Italy, was dignified by having no less an artist than Raphael to furnish designs for it; and his successors, catching the tone and manner of the great master, produced those numerous works which still dazzle us with the splendour of their colouring; while some of them, known as *amatorii*, are adorned with the portraits and names of ladies in the costume of at least three centuries ago. Then again there is the curious ware of Palissy, the hero of potters, who, when persecuted for his Protestant opinions, declared that no power on earth should

compel him to worship the images which he had made with his own hands. One of his favourite subjects is a basin or dish, representing the bottom of the sea, covered with fishes, shells, sea-weeds, and pebbles. The prevalence of a similar taste leads us to cover with beautiful pictures such common articles as dinner-plates and cups and saucers, which we soil with our food, and place in various positions on the table, all more or less unfitted for viewing a picture. This taste is gratified in spite of great difficulties in this art of enamel painting; for the artist has to grope his way, as it were, in the dark, painting with certain metallic oxides ground up in oil, which do not represent the colours intended to be produced until they have been passed through the fire. Then there are the dangers and difficulties of firing, whereby the piece may be cracked or crazed, or the surface scaled, or the piece may require to be retouched and passed again and again through the fire; and the only advantage that this difficult art presents over oil-painting is its permanence, for should the article escape fracture, it is otherwise indestructible. There is, however, no doubt that the taste for china ware greatly improved our earthenware. Under the influence of such a man as Wedgwood (whose factory at Etruria, in Staffordshire, is represented at fig. 331), and with the assistance of such a designer as the great sculptor Flaxman, a variety of beautiful wares for common use were issued at a cheap rate, the effect of which had a beneficial influence on the public taste. Wedgwood began life at the age of eleven as a thrower, but an attack of small-pox compelled him to give up this employment. The attack left him with a lame leg, which afterwards rendered amputation necessary. For some years his attempts to settle in life were not successful; but he appears on several occasions to have gratified his love of the beautiful by the manufacture of ornamental pottery. In 1759, he established a small factory of his own at Burslem, where he succeeded in making a white stone-ware, and afterwards a cream-coloured ware, some specimens of which he presented to Queen Charlotte, who was so pleased with it that she ordered a complete service, which obtained further marks of the royal favour: Wedgwood was named "The Queen's Potter," and his ware, "by command," *The Queen's ware*. He also invented a *terra cotta*, which could be made to resemble porphyry, granite, &c.; also *basalts*, or black ware, which would strike sparks with iron; white porcelain biscuit, with properties similar to the basalt; *bamboo* or cane-coloured biscuit; *jasper*, a white biscuit of great delicacy and beauty, fit for cameos, portraits, &c.; and a porcelain biscuit, used for chemists' mortars, &c. He also succeeded in giving to hard pottery the vivid colours and brilliant glazing which had been thought peculiar to porcelain; and with a true feeling for his art, he introduced a higher class of artists than had been hitherto accustomed to work in the potteries. The extension of Wedgwood's works led to the formation of a new village, which was named Etruria, from the resemblance of the clay dug there to the ancient Etrurian earth, and also, probably, to note the success with which he imitated the ancient Etruscan ware.

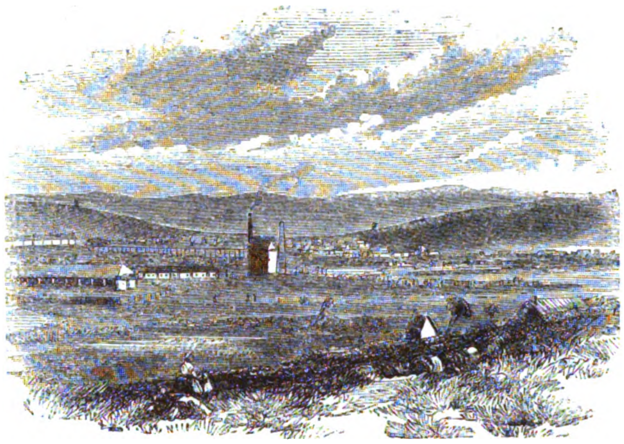
Painting on porcelain (fig. 323) does not greatly differ from other applications of the palette, except in the dingy nature of the pigments when first applied, and the brilliant creaminess of surface after the firing. The gold employed in gilding porcelain is first dissolved in *aqua regia;* the acid is then driven off by heat, and the residue, mixed with borax and gum-water, is applied to the wares with a hair pencil. When an article has to be ornamented with a circular line, it is placed on a *whirler* (fig. 326); and on holding a pencil against the article and turning round the upper part of the instrument, a circle is easily and truly described. When the articles have been baked, the gold appears of a dingy hue; but the beautiful lustre of the metal is brought out by burnishing with agate and blood-stone (fig. 325).

The manufacture of encaustic tiles has of late years risen into importance, as one of the results of improved taste in church architecture and decoration. These tiles are an example of veneering an inferior clay with a superior, as already referred to. The red clay is slapped into a block of a square section, and the tile-maker cuts from this a square slab by passing a wire through it, and upon this a facing of finer clay, coloured so as to form the ground of the tile, is applied: the tile is then turned over, and a facing is applied to the bottom to prevent warping: the tile is then covered with a piece of felt, put into a press (fig. 327), and a plaster-of-Paris slab, containing the pattern in relief, is brought down upon the face of the tile, and impresses in the soft clay or ground of the tile the design which is afterwards to be filled in with another colour. When the tile is removed from the press, the name of the maker is stamped on the back, together with a number of holes, to make the mortar adhere when the pavement is laid down. The device is then filled in by pouring over the tile a quantity of coloured slip (fig. 328), so as completely to conceal the surface: this is left for twenty-four hours to become hard, when the pile is placed on a small whirler, fig. 329; and a portion of the surface being scraped away, the pattern and the ground appear. The tile is lastly made smooth, and is polished with a knife, small defects are corrected, the edges are squared and rounded a little with sand-paper, and the tile, after having been dried in a hot room, is ready for firing.

Our export trade in earthenware and porcelain is of some importance. In the year 1856, the number of pieces of ware exported was 94,551,260, of the declared value of 1,331,106*l.* sterling. In 1859 our exports were of the declared value of 1,313,364*l.* and they were distributed in the following manner:

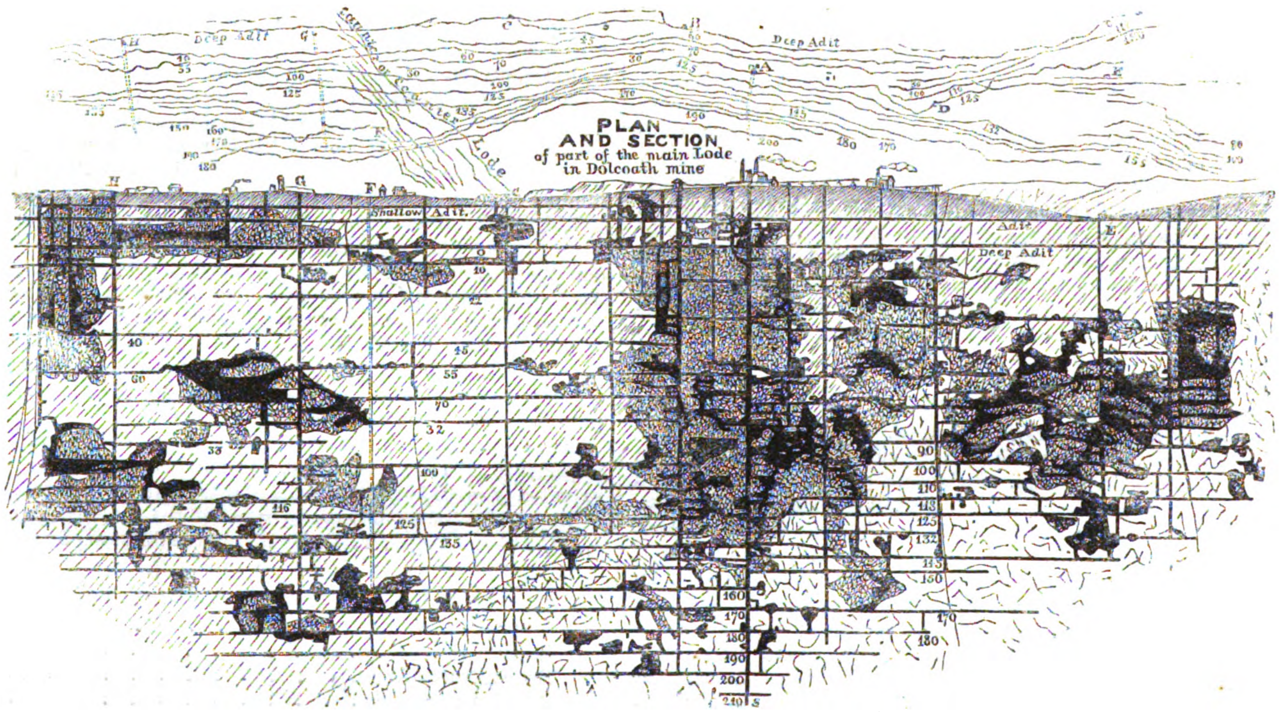
The United States of America took goods to the value of	£ 598,045
Brazil	57,055
British North America	63,013
British East Indies	80,994
Australia	84,088
Other Countries	430,169
	1,313,364

333. A WINZE.

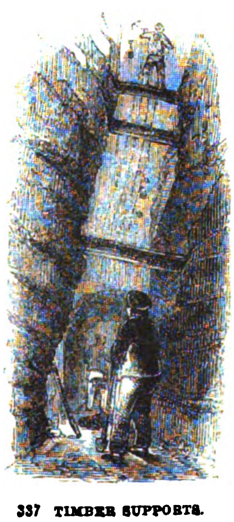


334. BURRA BURRA MINE, SOUTH AUSTRALIA.

335. WHIM SHAFT



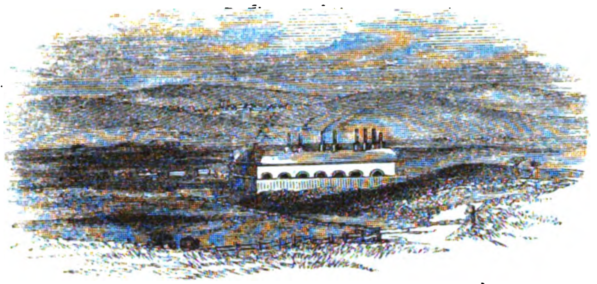
336.



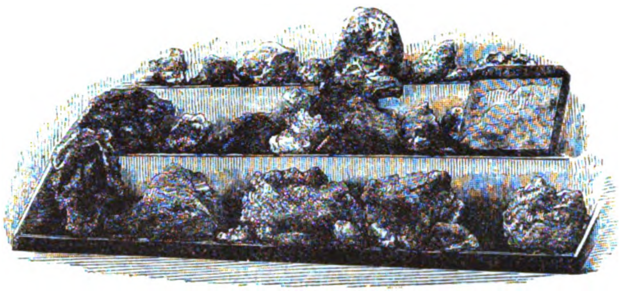
337 TIMBER SUPPORTS.

338. METHOD OF WORKING THE LODE AT BURRA BURRA.

339. SETTING A SHOT.

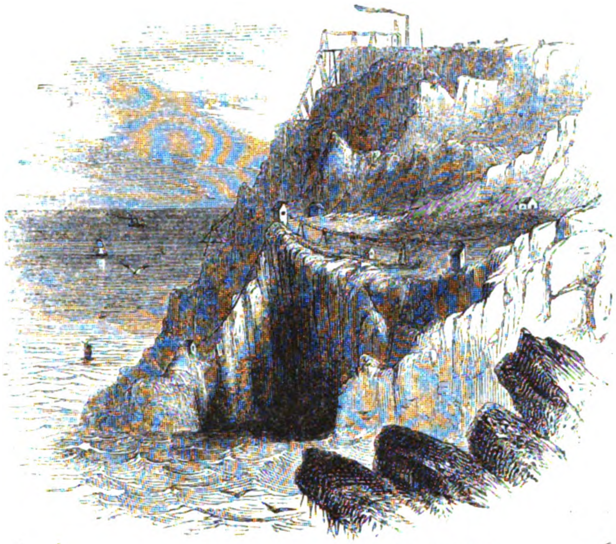


340. BURRA BURRA SMELTING HOUSES.

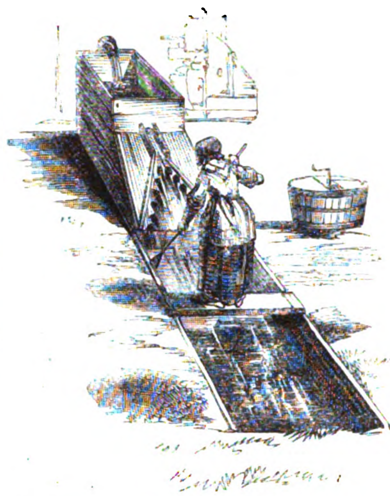


341. COPPER ORE.

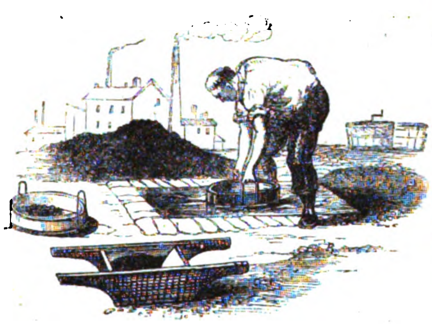
342. A PLATT.



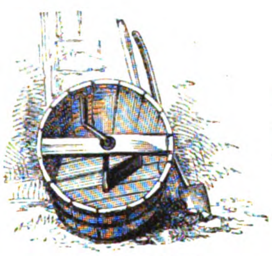
343. EXTERIOR WORKS AT BOTALLACK MINE.



344. BUDDLING.

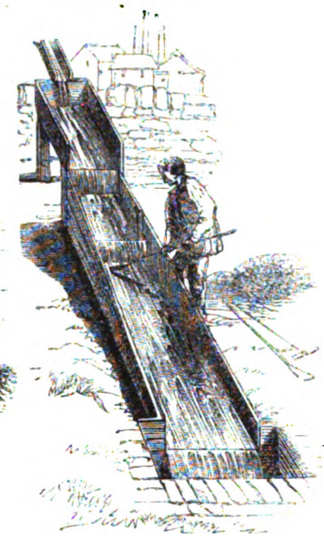


345. JIGGING.

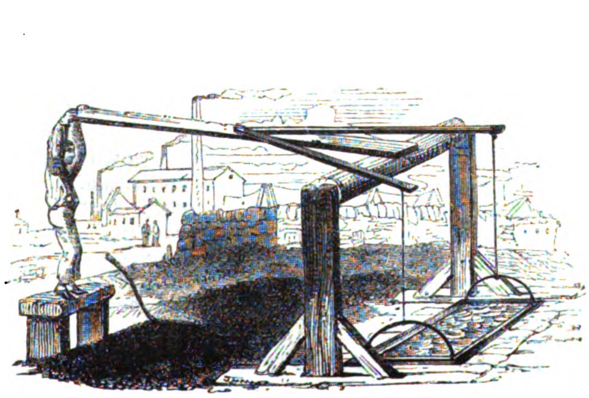


346. THE KIEVE.

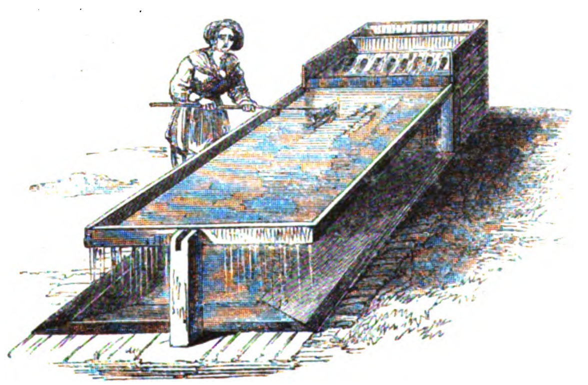
347. TOSSING OR TOZING.



348. TYING.



349. JIGGING MACHINE.



350. FRAMING OR RACKING.

XXII.—MINING OPERATIONS.

Nothing in the British islands excites so much surprise in an intelligent foreigner as the wonderful diversity of mineral wealth which it has pleased Almighty Wisdom to bestow upon this favoured land. We have rich stores of iron ore and abundance of fuel for reducing it, building-stones for constructing the furnaces, and fluxes for working the ores more easily. Iron and coal are so extensively distributed that it would occupy too much of our space to point out their localities. In Cornwall tin ore is abundant, copper in Wales, lead in Derbyshire and in the valleys of the Tyne, the Wear, and the Tees: in short, we have all the materials for constructing machines at the lowest possible cost, and abundance of fuel for working the steam-engine which sets them all in motion.

Our mineral riches are brought to the surface by means which vary with the mode in which they are deposited. In some cases the minerals form regular strata, and alternate with beds of rock of considerable extent, as in the strata of coal and iron ore of South Wales and Staffordshire, and the coal in the Newcastle and Durham districts: in other cases metallic ores may occupy cracks or fissures in the rocks, forming what are called *veins* or *lodes*. When these cracks are filled up with non-metallic substances, they are called *dykes:* but when they accompany veins of ore, and are at right angles thereto, they are called *cross-courses*. The metalliferous veins are not filled with metal in its pure or native state, but in the state of *ore*, that is, united with sulphur, oxygen, carbonic acid, and associated with salts of lime, baryta, quartz, and argillaceous matter.

The object of mining is to pursue one or more of these veins through the rocks which are met with in its downward descent, and to raise the ore to the surface. Supposing that by previous borings and other trials the position and direction of the vein is known, a pit or shaft is sunk to the depth of about sixty feet, when the men begin to work in a horizontal direction, and to cut or *drive* a horizontal gallery or level into the lode. This is usually done by two sets of miners, working in opposite directions, and the rubbish and the ore, if any, are raised by a common windlass. As soon as the two sets of miners have driven a level about one hundred yards, they cannot proceed farther for want of air; but in the mean time two other sets of men have been sinking from the surface two other vertical shafts to meet them, and in this way the work proceeds, the first level or gallery being driven to any required extent by sinking vertical shafts into it. While the horizontal gallery is being driven, the first shaft, called the *engine-shaft*, is sunk deeper, and at a second depth of sixty feet a second horizontal gallery or level is driven in the same direction as the first, and the vertical shafts are all sunk down to meet it. In this way galleries are formed at different depths, so long as the lode continues to be profitable. In the mean time the engine-shaft is sunk deeper than the lowest level, in order to keep the working shafts free from water, which rises in the mine from springs, or drains into it from the surrounding strata. Each successive level is also separately drained, in order that the lower workings may be kept as free from water as possible. The arrangement, such as we have described it, divides the rock into solid right-angled masses, each three hundred feet in length and sixty feet in depth. These masses are again subdivided by small vertical shafts, or *winzes* (fig. 333), into parts, called *pitches*. The principal gallery or tunnel by which the mine is drained is called the *adit*, or *adit-level*. To drive this from one point to another through a great extent of country, particularly where the work is commenced at both extremities, requires much skill. Attention is also required that the water, pumped up from the various channels, may not find its way back again to the workings. Some idea may be formed of the extent of the drainage required in extensive mines, from the fact that the various branches of the principal level in Cornwall, called the "Great Adit," through which the waters of the different mines in Gwenap and near Redruth are discharged, measure nearly thirty miles. The adit opens at the side of a hill at such an elevation as to discharge its waters into some stream or river, which flows into the sea, and in some cases the adit discharges into the sea itself.

The workings on different lodes are connected by *cross-cuts*, so that the ores may be brought to the principal shaft of the mine with the greatest ease. The work underground depends chiefly on the size of the vein and the value of the ore. When the lode is only a few feet wide, one gallery is sufficient; and as it is only necessary to leave a passage to extract the ore, the levels are here narrow and confined. But where the lode is broader, the open spaces are larger. When large masses of ore have to be taken out, pillars are left to support the *roof*, as one side of the wall or portion of rock which incloses the vein is called; the other wall being called the *floor*. But as these pillars contain valuable ore, the roof is often supported by *timbering* (fig. 337). The ore is extracted from the rock by means of gunpowder, for which purpose a cylindrical hole is bored in the rock, a charge of powder is introduced, a fuse inserted, the hole stopped or *tamped*, and after setting fire to the fuse the men retire till the explosion is over. Fig. 339 shows the men at work setting a fuze, or *shot*, as it is called.

When the ore has been detached, it is conveyed to the bottom of the principal shaft in wagons or *corves*, moving on tram-roads or rail-roads. The ores are lifted by machinery from the bottom of the shaft to the surface by a *whim*, worked by steam-power. In some of the Cornish mines it is not uncommon to sink two shafts near together: one, called the *engine-shaft*, being used for drainage, and a smaller one for drawing the stuff. The shafts are commonly four-sided; that intended for the extraction of the ore is called the *whim-shaft*. Fig. 335 represents what is called a *platt*, which is a sort of cavity at the extremity of a level, near the whim-shaft, for the purpose of collecting supplies of ore for filling the *kibbles* by which it is raised to the surface. The men are setting a *shot* for blasting, in order to enlarge the platt. A small kibble is shown hanging over a small *sump* or cavity at the bottom of the shaft for receiving the drainage water. Fig. 342 shows a platt complete, with the kibble hanging in the whim-shaft, which is boarded off from the platt, to prevent accidents. The method of working the lode at Burra Burra Mine (fig. 334) is represented at fig. 338. In this very successful mine the copper ore, instead of forming a vein, constitutes an enormous nodulous mineral deposit in clay. Some of the nodules are of large size; and there were specimens in the Great Exhibition (see fig. 341) measuring two and a half feet by two feet superficial, with a thickness of six inches.

Fig. 336 represents a plan and section of part of the main lode in Dolcoath Mine, Cornwall. In the upper part of the figure or plan, the ground is supposed to be transparent, to show the underground levels. The numbers attached to the lines which represent the levels give the respective depths below the adit; so that if perpendicular lines were let fall from this level upon such lines, they would cut them at the various depths marked in fathoms. In the lower figure or section the lines of levels and letters of reference correspond with the plan. In this section those portions have been left blank which have been cut for galleries in the levels, the shafts, and where *bunches* or accumulations of ore occur; while those parts in which the rubbish of the workings has been thrown back, and arranged so that the galleries or levels and the shafts should pass freely through them, are represented as being composed of broken fragments. The

killas or slate is white, and the granite dotted. The main lode cuts into granite in its eastern prolongation, and a tabular mass of granite is cut by the lode and apparently separated from the rock. Bunches of ore have occurred very irregularly, and the spaces occupied by them have been filled up with rubbish from other parts of the mine. Levels on the east have been driven into the granite in search of ore, but they have been abandoned; the sump or lowest part of the engine-shaft marked *s* is at the depth of 210 fathoms. At the time when this plan was made, the ores were drawn up by four shafts by three steam-whims, indicated on the surface: the position and number of the shafts, however, varies with the state of the mine; and as every shaft has its name, and every level is known by its depth, a mine resembles a town in which the streets are known by names and the houses by numbers.

When mines are situated near the coast, they often present rugged and sublime features. Near the Land's End, in Cornwall, the direction of the veins and the distribution of the ores direct many of the mining operations beneath the bed of the Atlantic. In the Botallack Mine, fig. 343, the miners followed the ore upwards into the sea; but as the openings were small and the rock hard, the water was excluded by plugging. During rough weather the sounds which penetrate the mine are described as being appalling.

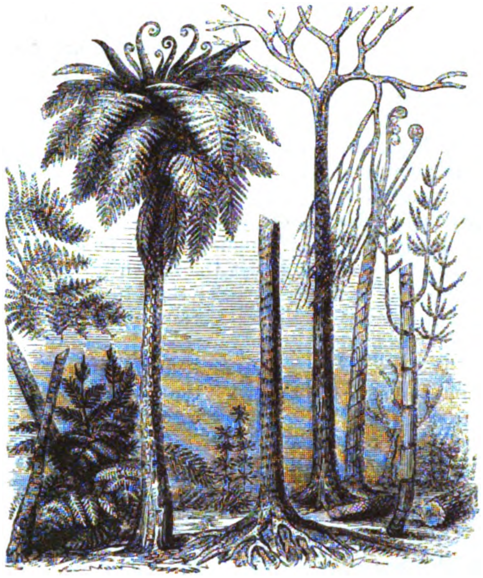
When the ore has been raised to the surface, it undergoes various operations previous to smelting. Tin ores are usually so far purified as to render the smelting a simple process. Copper ores, on the contrary, depend more on chemical than mechanical treatment for their purification; so that little is done except to separate stony matters, after which the ore is sent to Swansea, where coal is abundant, to undergo the complicated series of processes by which it is converted into metallic copper.

When the tin ores are raised, the first operation is to break them in pieces and to reject such portions as are too poor to repay the cost of *dressing*. The ore is then sent to the *stamping-mill*, which consists of a number of upright wooden beams or *stampers*, shod with iron: these are placed in a wooden frame, and lifted about ten inches by the cogs of a horizontal axle, the rotation of which thus gives a stamping motion to the upright wooden beams. The ore is placed on an inclined plane near the bottom of the stampers; and as these are lifted up, a portion of it slides beneath them, and is crushed by their fall. Water being let in, carries the crushed ore into pits, in the first of which the rough parts lodge, as well as the heavier portion of the powdered ore, called the *slime*, the rough ore when dressed being called the *crop*. The remainder, with the lighter slime, is retained in the second pit, and this when dressed is called the *leavings*. The dressing now comprises a number of operations, all of which depend on the fact that the metallic portion which is to be preserved is much heavier than the stony and earthy matters which are to be got rid of.

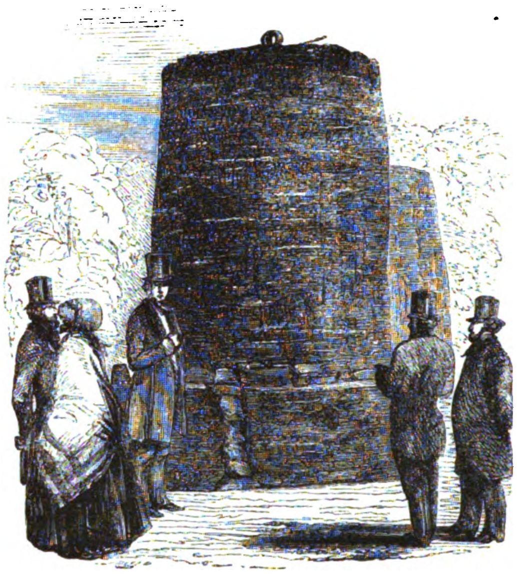
The first operation on the crop is called *buddling*. The buddle (fig. 344) is a wooden case fixed in the ground, one end being elevated: on the rim of the higher end is a board called the *jagging-board*, extending from side to side, and more inclined than the buddle. The operator spreads the ore on the jagging-board, cuts small furrows in it with the shovel, and letting in a current of water from the head of the buddle, the ore is carried into the case, where the finer and richer portions subside near the head, while the rougher and lighter portions are carried towards the lower part. When the buddle is full, it is divided into three or four parts, called *heads, first* and *second middle-heads*, and *tails*, the last being the poorest. These are again separately buddled. The heads are then *tossed* or *tozed* in a *kieve* (fig. 346) or large tub, about one-third filled with water, which is rapidly stirred by means of the stirrer shown in the figure, while a second workman gradually adds the ore with a shovel (fig. 347). When the kieve is nearly full, the stirring is stopped, and the kieve is struck with a hammer so as to assist the ore in arranging itself into strata according to their density; the ore in the lowest part of the kieve being generally fit for smelting, while for the other portions the operations are repeated.

The first and second middle-heads are treated in a somewhat similar manner, after which they and the other ores which have been thus far treated are roasted, in order to get rid of ores of copper, iron, or zinc, and when removed from the furnace the ore is sifted, again tossed and buddled, and is then ready for the smelter. Some kinds of ore after roasting require *tying:* the *tye* (fig. 348) is a long, narrow, inclined furrow, through which passes a stream of water, and the ore being placed at the head is agitated with a broom, so that the rough and lighter particles are carried to the lower part, while the ore at the head is fit for the smelting-house. The remainder goes through the operation of *jigging* (fig. 345), which is performed by plunging a copper-bottomed sieve, containing two or three shovelfuls of ore, into water, and working it about in such a way that the different parts may easily arrange themselves in the order of their respective densities; the lighter portions which come to the top are scraped off, a fresh supply of ore is thrown in and jigged, until at length the weight of the richer portions at the bottom of the sieve is too great for the operation to be continued. It is then removed for the smelting-house. In this operation the *jigging-machine* (fig. 349) is sometimes used: its construction will be understood by referring to the figure.

The poorer portions of the ore, which have been rejected in previous operations, undergo various forms of treatment, known as *trunking, framing*, or *racking*, but not differing in principle from the former. In framing or racking, fig. 350, the frame is a flat table with a rim round it: it is suspended on pivots in an inclined position, but is fastened by a kind of latch: at the upper end is a jagging-board similar to that of the buddle, and connected with a frame by a movable sloping piece of wood to prevent the ore from falling between the board and the frame: below the frame are two boxes, which, being placed end to end, extend its whole length; while, at the lower end of the floor, a space of two or three inches allows the water to escape. The woman spreads on the jagging-board a portion of slime, and, with a small toothless rake, makes small furrows in it; and the stream of water which is now let in, carries the ore from the board to the frame: the richest part rests at and near the head; the poorer portions move lower down, while the impurities are carried off by the water and escape by the bottom. When enough has been collected, the latch is lifted, and the frame being turned on the pivots, the ore is swept into the boxes beneath: the best into the upper, and the inferior ore into the lower box.

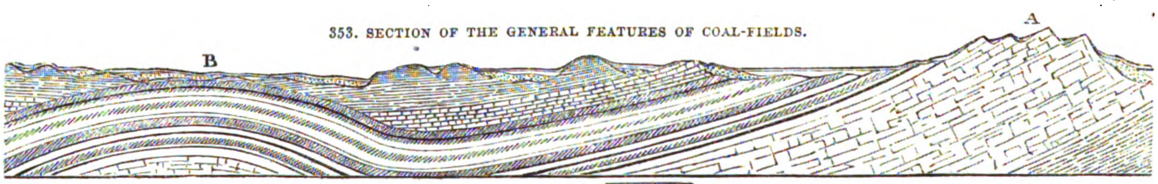


351. PLANTS FORMING COAL.—(*Restored*).



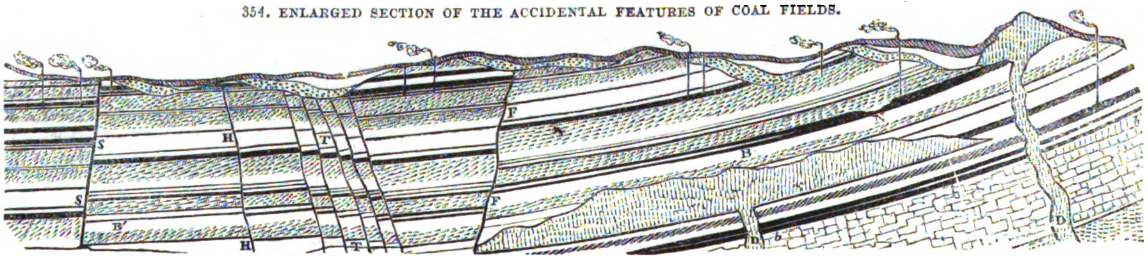
352. IMMENSE BLOCK OF COAL.

353. SECTION OF THE GENERAL FEATURES OF COAL-FIELDS.



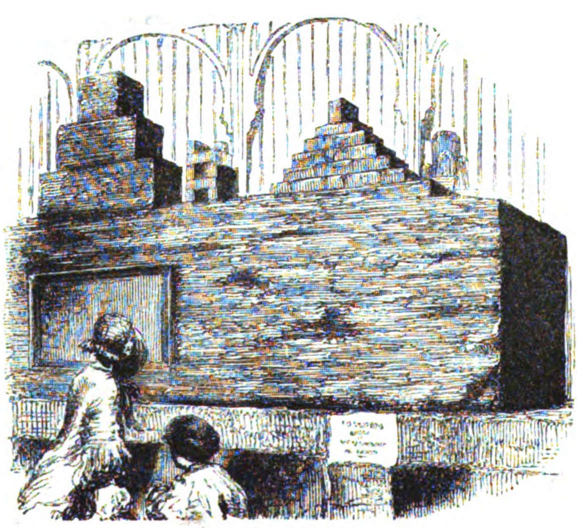
Diluvium (or gravel), alluvium, and mould.
Carboniferous shales, or slaty clays.
———— grits, or coarse sandstones.
Seams of Coal.
New Red Sandstone, and red or variegated marls.
Magnesian Limestone.
Mountain, or Carboniferous, Limestone.
Old, or Lower Red Sandstone.

354. ENLARGED SECTION OF THE ACCIDENTAL FEATURES OF COAL FIELDS.



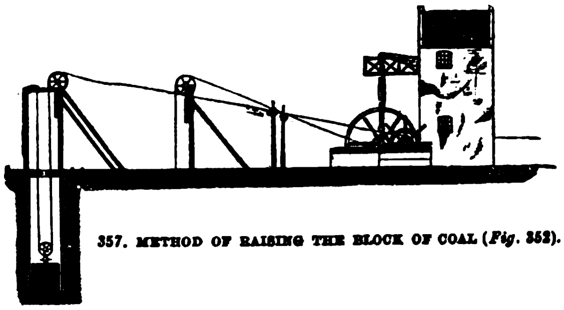
Basalt, and other igneous rocks. **Anthracite, or natural coke.**

D D, Whin Dykes. F F, S S, Faults, or Slip Dykes. T T, Troubles. H, Hitch, or Step. *b* and B B', Bands. N, Nip, or Baulk.

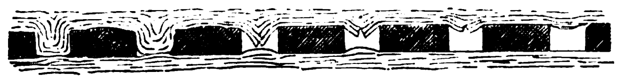


355. BLOCK OF STAVELEY COAL.

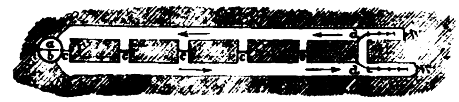
356. FRACTURE OF COAL.



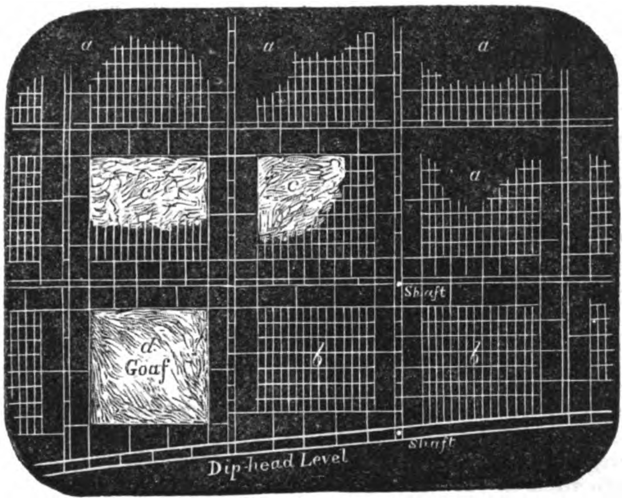
357. METHOD OF RAISING THE BLOCK OF COAL (*Fig.* 352).



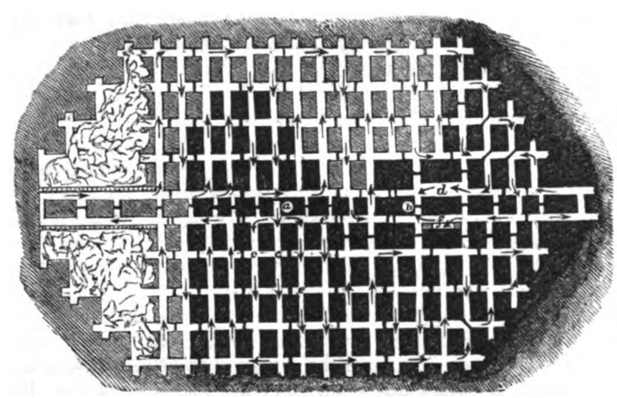
358. A CREEP.



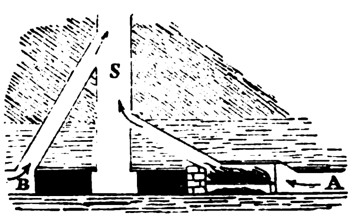
359. VENTILATION OF BORDS.



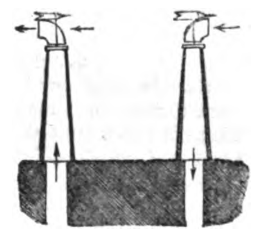
360. PLAN OF COAL-MINE.



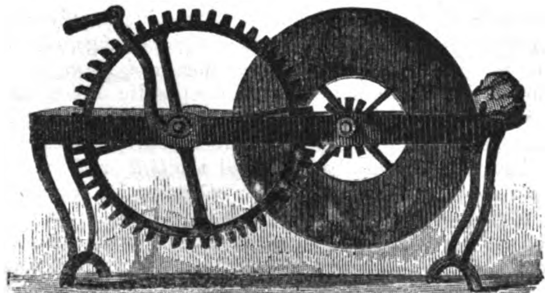
361. VENTILATION OF A COAL-MINE



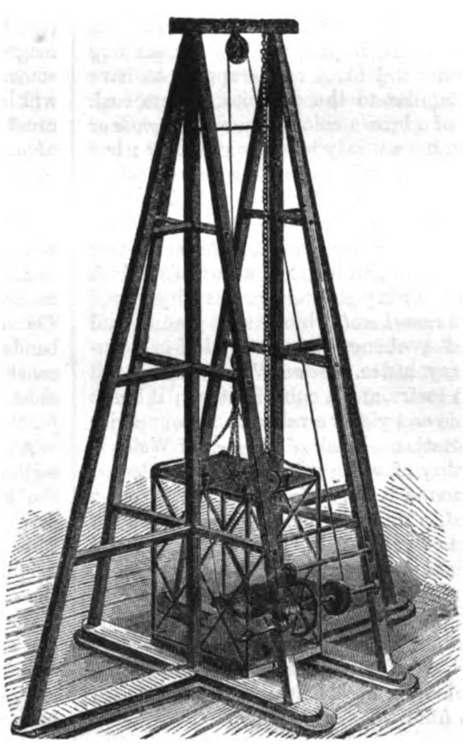
362. DUMB FURNACE.



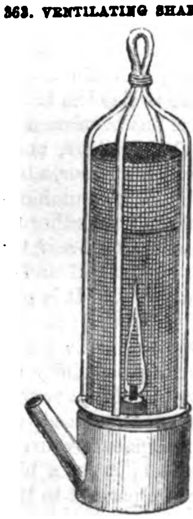
363. VENTILATING SHAFTS.



364. THE STEEL MILL.



365. FOURDRINIER'S MINERS' APPARATUS.



366. THE DAVY.

XXIII.—COAL.

The vast deposits of coal in Great Britain form one of the sources of her commercial greatness. Coal is superior to every other description of fuel in the wide range of its usefulness. We use it for cooking our food, and for warming and ventilating our rooms; we light our streets and our houses by means of the gas which we distil from it; we use it for reducing ores to the metallic state, and for putting in motion the locomotive, the steam-boat, and the stationary engine, and this last sets to work innumerable forms of automatic machines. Our supply of this valuable fuel is as abundant and extensive as it is conveniently deposited for distribution. Had it been placed in the midst of high mountains, far from the convenience of water-carriage, it would have lost much of its value; but as it is, coals are found in or near rich valleys and low plains near the seas and large rivers, well adapted for home consumption in the busy manufacturing towns placed on their banks, and for distribution by water-carriage or by railway.

The examination of a lump of coal renders it evident in most cases that it was formed by the action of certain chemical forces on wood or other vegetable matter. The most rudimentary form of coal is *peat*. In situations where clay is spread over gravel, and water is prevented from escaping, muddy pools are formed, round the borders of which aquatic plants flourish, and gradually creep in towards the deep centre. Mud having accumulated round their roots and stalks, a spongy mass is formed, adapted to the growth of moss, which, together with the spears of the *Sphagnum*, now thrives: this absorbs much water, and continues to shoot out new plants above, while the old ones are decaying and becoming compressed into a solid mass below. Thus the water is replaced by vegetable matter, and the marsh is filled up, while the central or moister portion, growing more rapidly, gradually rises above the edges until the surface has attained such an elevation as to discharge the surface-water and to flood the adjacent country. In this way peat bogs are formed and extend their dimensions, one generation of vegetable matter flourishing upon the ruins of its predecessor. In other cases trees and plants may be drifted from a distance and accumulated in particular localities, as in the *deltas* of the Mississippi and other large rivers; and under the action of an elevated temperature and other chemical forces, they form irregular deposits, which impregnate the surrounding strata. In this way bitumens and fossil resins appear to have been formed, in a manner similar to the deposits of true coal. There is also a kind of coal of a brown colour, known as *lignite* or *brown coal*, which usually retains a woody lamellar structure; but the most highly prized variety of coal is the *bituminous* or *caking* coal, which is so abundant in the British coal-fields. It occurs above the old red, and beneath the new red sandstone, in what are called the *coal-measures*. There are several varieties of this coal, such as the *Scotch Parrot coal*, which is of a brownish black colour, and of a slaty structure; it yields a large quantity of gas. There is also the Lancashire *cannel coal*, which burns readily, and hence has been used as *candles*, whence the name. It has a conchoidal fracture, and a waxy lustre. *Newcastle coal* has a full blue-black colour, a brilliant lustre, and a cubic fracture; it burns with a bright luminous flame and yields a valuable coke, superior to that of the other two varieties. Much of the coal of Wales is known as *steam-coal*, the quality of which is intermediate between bituminous coal and anthracite; it burns freely, and gives out a steady heat. It is preferred in the steam-navy, since it does not readily crumble in the hold of the vessel during its rolling, and yields but little smoke, a circumstance favourable to a ship of war in the vicinity of an enemy. *Anthracite*, *stone-coal*, or *culm* contains only a very small portion of volatile matter, so that it burns with a steady red glow, almost without flame. It splinters into fragments when heated, whence it is inconvenient in its use as a fuel; it has a black colour, a high lustre, and a lamellated fracture parallel to the bed from which it is taken.

The fossil fuel of this country was represented in the Great Exhibition of 1851 by the immense block represented in fig. 352. It is a good specimen of the Staffordshire thick or ten-yard coal. Its height was nine feet six inches, the circumference twenty-one feet ten inches, and the weight thirteen tons; it was conveyed seventy yards underground to the bottom of the shaft, and was raised from a depth of 165 yards by the ordinary steam-engine, as shown in fig. 357. The mass of coal represented in fig. 355 was raised from a shaft 459 feet in depth, at Staveley, in the county of Derby. This block was seventeen feet six inches in length, six feet in width, and four feet in thickness. The thickness of the seam was six feet; the cubical fracture of this coal admits of its being split into rectangular masses like bricks, so that it is well adapted for stowage in steamers. Fig. 356 represents the crystalline fracture of certain kinds of Welsh coal.

The coal-fields of our island are usually divided into:—1. The Great Northern District, which includes all the coal-fields north of the Trent. 2. The Central District, including Leicester, Warwick, Stafford, and Shropshire. 3. The Western District, subdivided into the North Western, which includes North Wales; and the South Western, which includes South Wales, Gloucester, and Somersetshire. In these fields the coal is separated into a number of distinct layers or strata of various thicknesses, by means of layers or strata of a slaty clay called *shale*, and a coarse hard sandstone called *grit*, forming what are termed the coal-measures, as already stated. The strata of coal, called *seams*, are very thin compared with the associated rocks; they extend under large tracts of country, and vary in thickness from a few inches to six or eight feet, except in Staffordshire, where there is a seam thirty feet thick; but this is now nearly all worked out. The interposed strata of grit and shale often exceed 700 feet in aggregate thickness. Under this is the mountain limestone, which rests on the old red sandstone already noticed. These deposits do not occur in horizontal unbroken strata, but have at various times been disturbed by some upheaving force from below, so that the coal-measures in many districts have been made to assume the shape of a huge trough or basin rising on all sides from a central point; the sides of the basin being composed of sandstone or limestone, and the middle filled up with magnesian limestone and new red sandstone. Fig. 353 will convey some idea of the arrangement of the coal-measures, by which it will be evident that the edge or boundary-line of each stratum must appear at the surface, somewhat like the concentric layers of an onion cut in two. This appearance of the coal at the surface is called the *basset* or *outcrop*, or "coming to the day," as the colliers have it. Few coal-fields however, are bounded on every side by the outcropping of older strata: the upheaving force which converted the horizontal strata into basin-shaped arrangements probably produced certain fissures or fractures, often nearly vertical, and stretching through the whole mass (fig. 354). These rents are called *dykes*, because they divide the seams or bands of coal into fields: they are also called *shifts*, as the miners consider them to have shifted the strata on their sides; but the most common name is *faults* or *troubles*, from their troubling or putting to fault the pitmen.

A coal mine does not greatly differ from the mine already described. A shaft is sunk, and a broad, straight passage, called the *bord*, or *mother-gate* (from the Saxon for *road* or *way*), is driven from it into the seam of coal in opposite directions. This bord is twelve or fourteen feet broad, and of the whole height of the seam, so as to expose the rock above, now called the *roof*, and also the stratum below, called the *thill* or *floor*. A main level, or *dip-head*, is also driven for collecting the water of the mine: from this gallery other galleries are driven, and the direction of the bords is arranged so as to follow the natural cleavage of the coal which forms their sides. When a bord has been excavated some distance, narrow passages called *head-ways*

are driven from it at regular intervals on both sides; and when these have proceeded eight or ten yards, they are made to communicate with other bords, which are open parallel to the first, and on each side of it. In this way, the bed of coal is laid open and intersected by broad parallel passages, about eight yards apart, communicating with each other by the narrower headways which cross them at right angles, and also traverse the whole extent of the mine, immense pillars of coal being left standing between the two. Fig. 360 represents the plan of one story of such a mine, which is worked by what is called *pannel-work*: the coal is extracted from each pannel in succession, and the large pillars of coal are left between the bords to support the roof: the pillars are next removed, the roof being meanwhile supported by timber props; and when all the coal has been got out, the props are removed and the roof falls in. In fig. 360, *a a* are pannels not entirely laid open by galleries; *b b* are laid open, but the pillars are not yet removed; in *c c* the pillars are being removed and the roof is falling in, its ruins forming what is called *goaf;* the pannel *d* is entirely worked out and abandoned. While the first seam is being worked, the shaft may be sunk to a second or a third seam, where similar operations may be carried on. The regularity of the workings may, however, be disturbed by many accidents. If the roof be of hard sandstone, and the floor of soft clay, the downward pressure may displace and force up the floor; forming what is called a *creep*. But if the roof be soft, it will sink in and form a *crush*; and if both roof and floor are moderately hard and tough, they may gradually meet midway, as shown in fig. 358, filling up the passages. There is also a terrible accident to which the collier is exposed from the escape of an inflammable gas generated by the coal itself; which, mingling with the air of the mine, forms an explosive mixture liable to be fired on the approach of a lighted candle, and spreading death and destruction around. This gas is a compound of carbon and hydrogen (carburetted hydrogen), called *fire-damp* by the miners. When an explosion unhappily takes place, the dust of the mine, consisting, for the most part, of innumerable small particles of coal, undergoes combustion also, forming an irrespirable gas (carbonic acid), called by the miners by the expressive name of *choke-damp*, from its producing spasm of the glottis, and preventing respiration. But as a light of some kind is necessary to the *hewers*, who excavate the coal, and the naked flame is dangerous, light was formerly obtained by the *steel-mill*, fig. 364, by which a stream of sparks was produced by the rapid revolution of a rim of steel against a piece of flint. This contrivance, however, gave but a feeble light, and no real security: candles continued to be used, until several deplorable accidents determined the coal owners to seek the aid of science. Sir Humphry Davy was applied to; and, on investigating the subject, he found that if the flame of a lamp or of a candle were surrounded with wire gauze, the flame would not pass through the meshes to fire the explosive mixture on the outside. Such is the origin of the *Miner's Safety Lamp*, fig. 336, called by the pitmen the *Davy*. George Stephenson was also the inventor of an efficient safety lamp, called by the miners the *Georgy;* but his light was quenched in the lustre of his distinguished rival.

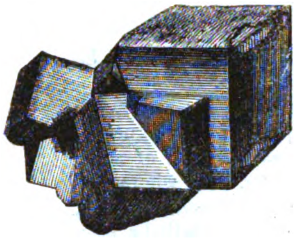
Safety lamps are, however, sources of danger, where men, from constant familiarity with peril, become careless or indifferent. Hence an efficient system of ventilation is now regarded as of as much importance as protected flames. In a mine where there is only a single shaft, provision is made for the ascending and descending currents of air, by dividing the shaft into two portions, as at *a b*, fig. 359. It is not safe for the men to be more than a few yards in advance of the ventilating current; hence in commencing a new seam it is usual to begin with two parallel bords, connected at intervals by cross passages, which are successively stopped up by wooden partitions, *c c*, fig. 359, so as to leave no communication except through the one last opened, or that farthest from the shaft: temporary partitions are also placed at *d d*, to cause the current to circulate quite up to the pitmen at w w. In a more advanced state of the works, the direction of the current through every part of the mine, by means of partitions called *stoppings*, becomes a matter of some complexity, as will be seen by the plan, fig. 361, where the arrows represent the course of the air from the *downcast* shaft *a*, through all the galleries to the *upcast* shaft *b*. It will be seen that in most cases the current is allowed to divide itself between the parallel bords; so that if any part of the mine is more *fiery* or dangerous than the rest, from the increased escape of fire-damp, the current can be confined to one course, and thus have its velocity doubled: by which means the dangerous gas is more rapidly drawn out of the mine; while in parts containing but little gas, the same current may be allowed to expand into three passages; such is the system of *double* and *treble coursing*. *Double stoppings* are also represented in fig. 361; these are pairs of doors, constantly attended by a door-keeper, whose business it is to keep them always shut, except when men and horses are passing through; so as to separate a dangerous from a more secure part of the mine.

The ventilating current is set in motion by a large fire, which is kept burning at the bottom of the upcast shaft. To prevent the foul air from the more fiery parts of the mine from coming into contact with the flame, it is usual to divide the air as it enters the mine by the downcast shaft *a*, fig. 361, into two distinct currents; one of which proceeds through the passages *e e* into the safest parts of the mine, and the other, *c c*, through the fiery parts, as represented by the lighter shade, including the *goaves*, or abandoned workings, where gas is apt to accumulate. The purer current is allowed to pass through the furnace *f*, before it enters the upcast shaft *b*. The other current is conducted through *d*, and enters the shaft at a higher level, by a channel cut obliquely through the roof of the seam, as in fig. 362, where S represents the upcast shaft, B the impure current, and A the purer current which feeds the furnace; which, in such a case, is called a *dumb-furnace*.

A jet of steam, made to play in the upcast shaft, also acts as a powerful ventilating force. Ventilation is also assisted by erecting towers or chimneys over the ventilating shafts, with large cowls turned by vanes, as in fig. 363, so that one may always present its mouth and the other its back to the wind.

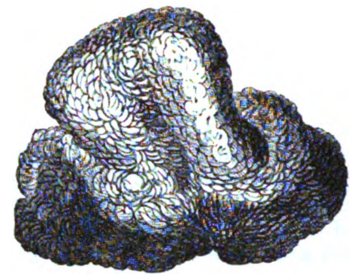
The pitmen are also liable to danger by their ordinary mode of ascent and descent in the shaft, which is usually by a tub suspended by a rope or chain, the breaking of which is not an uncommon accident. To prevent the danger from this source, the apparatus, fig. 365, has been adopted at some pits. It consists of a cage or basket, for the men or the coal, attached to guide rods or chains down the side of the shaft; and should the rope break, certain springs or arms attached to the top of the cage become liberated and wedged upon guide-rods, whereby the cage becomes fixed. The coal is got out by blasting; and such is the force of two or three *shots* of gunpowder, that from sixty to eighty, or one hundred tons of coal may be brought down at once. The coal is put into *corves* and drawn along tram-roads, by lads called *putters*, to the principal galleries or headways, where it is received into wagons called *rolleys;* a number of which are drawn by a horse to the bottom of the shaft, and the coal is then raised to the surface by steam-power. At the surface, the coal is passed over screens in order to separate the pulverized portion: the screens are usually bars of iron half an inch apart, mounted in a frame-work and sloping so as to allow the coal to slide down into the wagons below. The small coal which passes through the screen is either delivered for immediate sale, or hoisted up and re-screened into *rough*, *small*, and *dust*. The great demand for coke now allows the small coal, which was formerly waste, to be profitably employed.

The quantity of coal raised in the United Kingdom in the year 1858 amounted to 65,008,649 tons, of which 6,077,271 tons were exported to foreign countries; by far the largest quantity being taken by France.

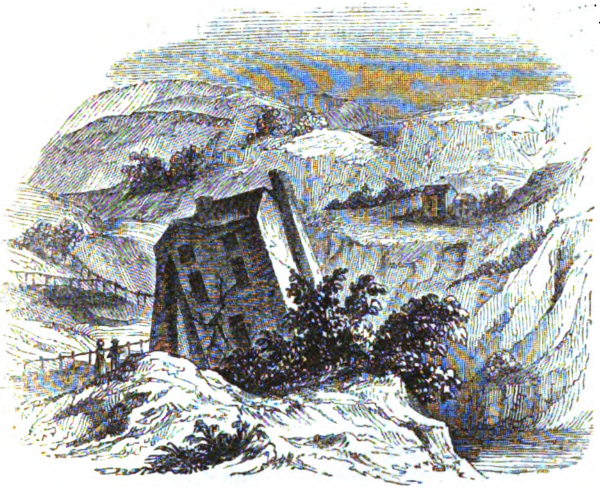


367. IRON PYRITES.

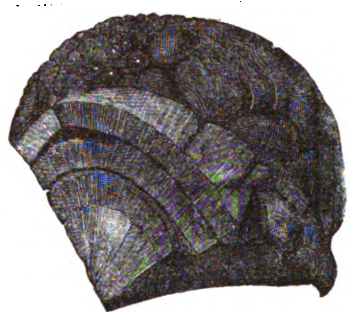
368. COAL AND IRON PIT.



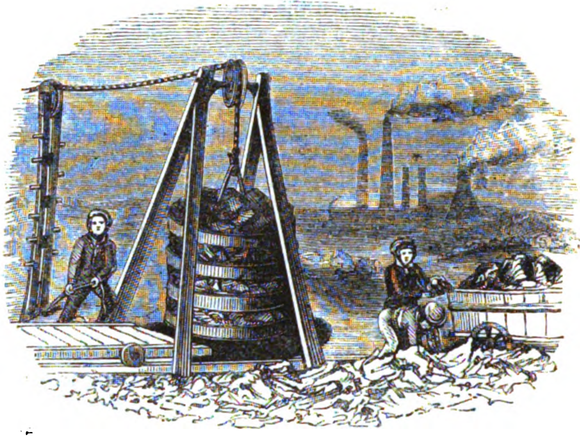
369. SPARRY IRON.



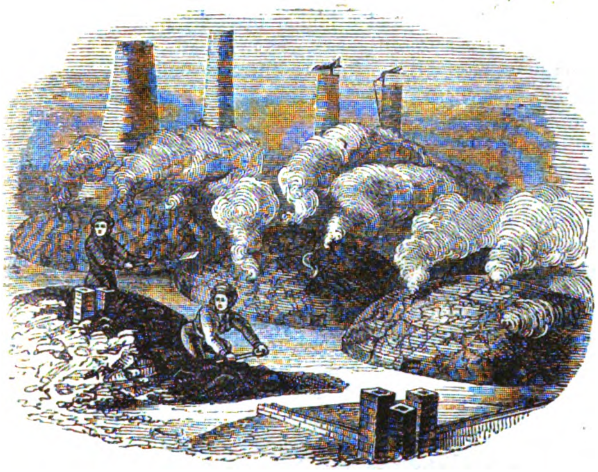
370. EFFECTS OF MINING



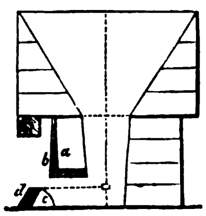
371. HÆMATITE.



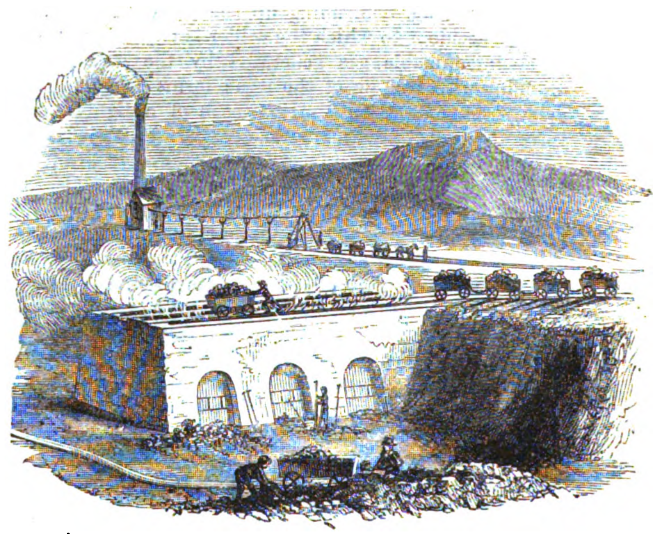
372. MOUTH OF THE PIT.



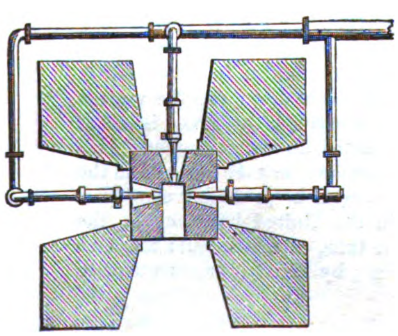
373. ROASTING THE IRONSTONE IN HEAPS.—(*Dudley.*)



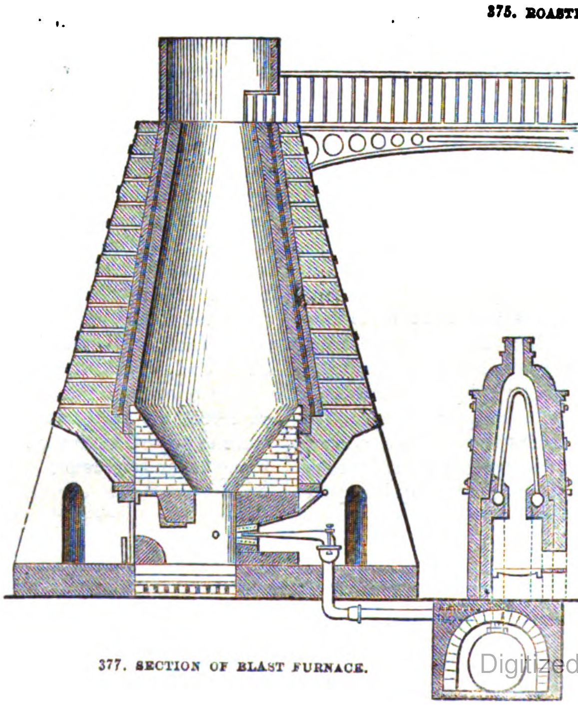
374. LOWER PART OF FURNACE.



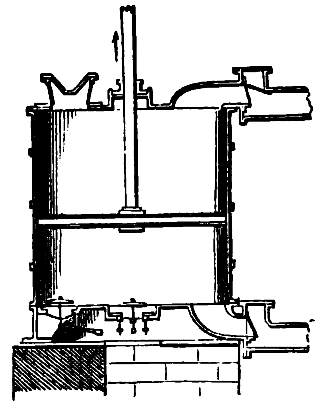
375. ROASTING THE IRONSTONE IN KILNS.—(*Colebrook Dale.*)



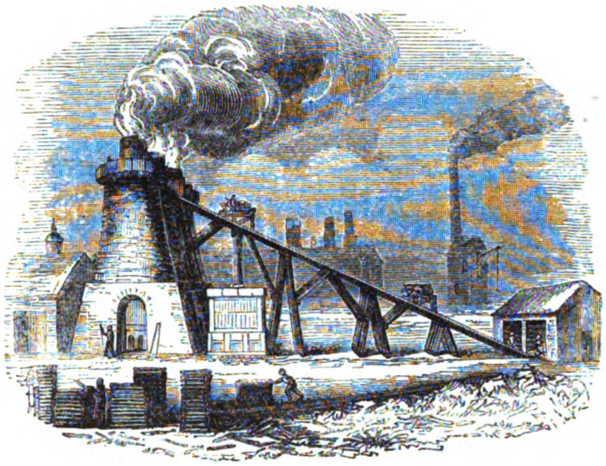
376. ARRANGEMENT OF TUYERES.

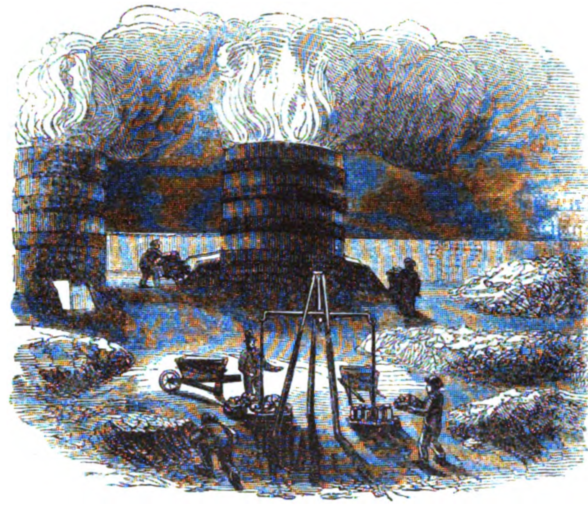


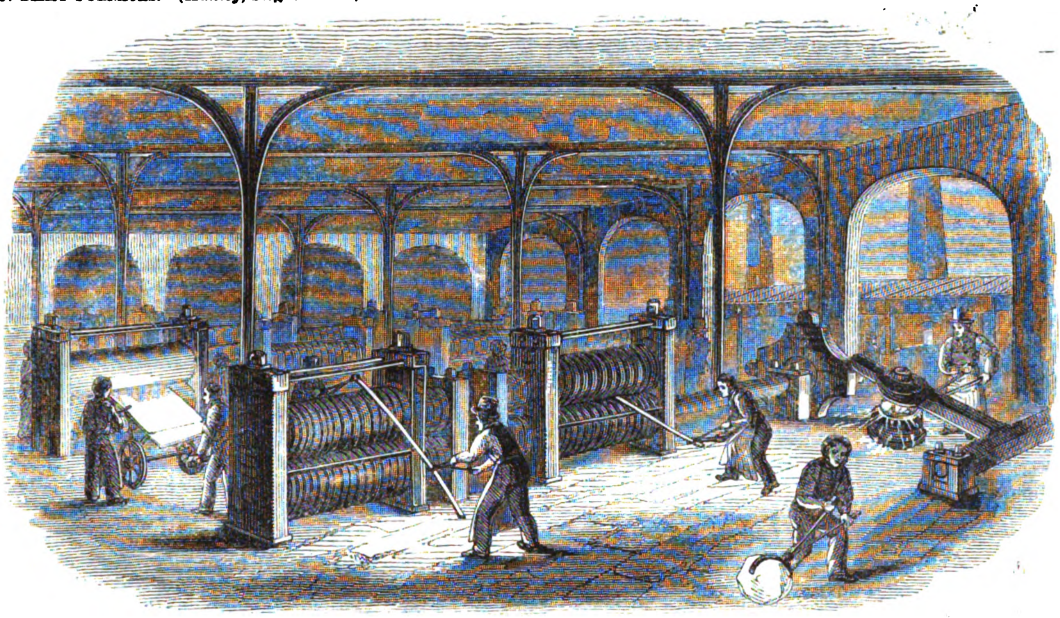
377. SECTION OF BLAST FURNACE.

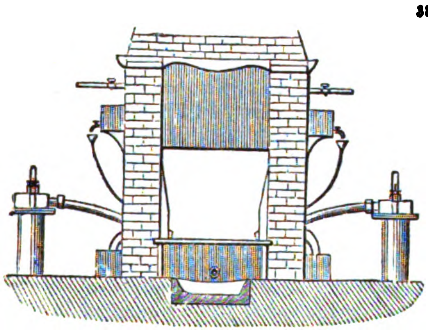


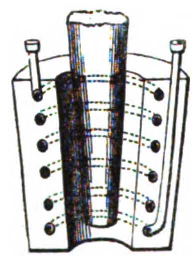
378. SECTION OF BLOWING APPARATUS.

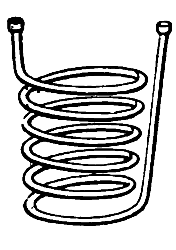

379. BLAST FURNACES.—(*Hanley, Staffordshire.*)

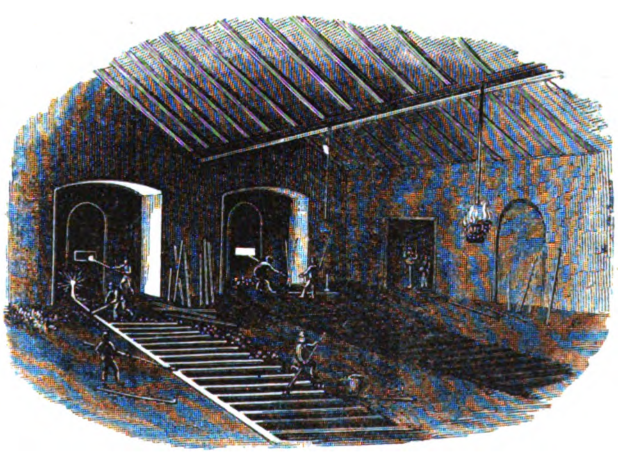

380. MOUTHS OF BLAST FURNACES.—(*Colebrook Dale.*)

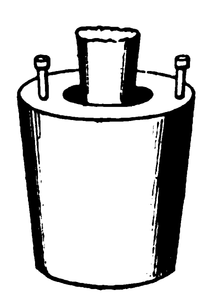

381. THE FORGE.—(*Colebrook Dale Company's Works at Horse Hey.*)


382. SECTION OF REFINERY.


384 B.


384 A. WATER APPARATUS.


383. CASTING.


384 C. WATER APPARATUS

XXIV.—IRON.

The iron-works of Great Britain produced in 1858 the amazing quantity of 3,456,064 tons of pig iron, the value of which at the furnace, estimated at 3*l.* per ton, gives the total value of the crude produce as 10,368,192*l.* The innumerable uses to which this truly valuable metal is applied, and the increasing demand for it, at home and in other countries which are not blessed with our sources of mineral wealth, can alone account for this vast production. No other metal represents so many valuable qualities as iron: rendered fluid by heat, it will assume the form of the mould into which it is poured, so that numerous useful articles can be at once prepared by the cheap and ready method of casting: it can be drawn out into bars of any required degree of strength, or into wires of any required fineness: it can be rolled out into plates or sheets: it can be twisted and bent to any required form: it can be made hard or soft, sharp or blunt. The ploughshare and almost every implement of husbandry are formed more or less of iron. There are few machines of which this metal does not form a part; while those important machines used by the engineer in constructing machinery are mostly of iron. The tools of every mechanic depend more or less upon iron. We travel on iron railways, and are drawn by iron horses; we make long voyages in iron ships; we pass over iron bridges; we sleep on iron bedsteads; we sit in iron chairs; pillars and girders of iron enter into the construction of many houses—sometimes whole houses are constructed of iron; we make lighthouses of iron, and send them in pieces to distant parts of the globe; and, as a worthy conclusion to this suggestive list, we may add that churches of iron are not now uncommon.

Iron exists in the earth in a variety of forms. In combination with sulphur, it is the common *iron pyrites* (fig. 367); but sulphur being an injurious ingredient, this form of the ore is seldom or ever used in the manufacture. The ores most in use are those in which the iron is united with oxygen, such as the *magnetic* iron ore, which produces a bar-iron of great value in making steel; *specular* and *micaceous* iron ore, or *iron glance*, are native oxides of iron; and there is also the *hæmatite* or *red iron-stone* (fig. 371), which is abundant near Ulverstone in Lancashire, and is much used in making iron for wire and for iron-plate. But by far the largest quantity of iron is manufactured from ores which are not rich in iron, but are associated with the fuel required for their reduction. Such is the *clay iron-stone* or carbonate of iron of Staffordshire, Shropshire, Wales, Derbyshire, Scotland, and other parts of Great Britain. It generally contains from thirty to thirty-three per cent. of metallic iron. A specimen of carbonate of iron is represented in fig. 369; but this is a much more favourable example than the dull worthless-looking stone obtained from our pits, in which the oxide of iron, combined with carbonic acid, is mixed with clay, lime, and other earths. The iron-stone usually occurs in horizontal strata or *bands*, and also in lumps, some of several hundred pounds weight, and others not larger than a small bullet. A variety of clay iron-stone known as *black-band*, contains, in addition to the ordinary earthy substances, a quantity of carbonaceous matter which assists in the roasting of the ore.

The Dudley coal basin is an eminent example of the great facilities possessed by this country for the manufacture of iron. Here we find the iron-stone associated with coal, the limestone required for the flux, and the refractory fire-clay used in constructing the interior brick-work of the furnaces. Fig. 368 represents the method of getting out the iron-stone at Dudley. A shaft being sunk, galleries are driven at different depths into the coal, or into the iron-stone. The ore or coal is placed in small wagons moving on a tram-road, and is thus drawn to the mouth of the pit. Here a kind of circular platform is loaded with the stone, the mass being supported by loose flexible bands of iron (fig. 372). When drawn to the top, a platform is wheeled over the mouth, and upon this the load is rested while being unpacked. The extensive excavations thus made underground cause the surface to give way: the walls of houses crack and totter, and are only prevented from falling by building massive buttresses against them, as in fig. 370, which represents a portion of the iron district of Colebrook Dale.

The first operation in the manufacture of iron is *roasting* the ore: this may be done in heaps, or in kilns. When roasted in heaps, a layer of small coal is spread on the ground: upon this a quantity of iron-stone, then more coal: on this the iron-stone is piled into a wedge-shaped heap, and the whole is covered with small coal. In forming the heap, channels are left for the admission of air, as shown in fig. 373. When roasted in kilns (fig. 375), a stratum of coals at the bottom of the furnace is sufficient for the purpose. Coal is also coked by burning it in large heaps.

The furnace in which the iron ore is smelted, is represented in section in fig. 377. It consists of five principal parts, which, reckoning from the bottom upwards, are: 1. The *Hearth*, which is composed of a single block of quartz grit, about two feet square. 2. Upon the hearth is a four-sided cavity called the *Crucible*, slightly enlarging upwards. 3. The part above this is in the form of a funnel or inverted cone, called the *Boshes*: this is the widest part of the interior, above which is 4. The *Cavity* of the furnace, extending in a conical form to the height of thirty feet and upwards. Above this is 5. The *Chimney*. The first three parts are represented separately in fig. 374, with a few more details: *c* is called the *dam-stone*, and *d* the *dam-plate*: from the top of the latter proceeds an inclined plane to allow the scoria to flow off: *a* is called the *tymp-stone*, and *b* the *tymp-plate*, for confining the liquid metal in the hearth; the space under the tymp-plate is rammed with loam or fire clay, called *tymp-stopping*. About two feet above the hearth, there are three openings in the sides of the crucible, for the admission of the ends of blast-pipes, through which air is forced into the furnace. The arrangement of the blast-pipes is shown in fig. 376, while the construction of the blowing apparatus is shown in fig. 378. In the latter arrangement the upward motion of the piston expels air along the top exit-pipe, a portion of which is shown to the right, while the downward motion of the piston expels air along the bottom exit-pipe, and these two pipes thus afford a continuous supply of condensed air to the pipes, fig. 376. It is evident that during the ascent of the piston, air enters by the bottom valves, which open upwards, and that during the descent of the piston these valves remain closed, and the upper valves fly open. The blast-pipe which enters the furnace is called a *tuyere* (pronounced *tweer*), and is protected from the intense heat by the method shown in fig. 384 A, B, C: a spiral pipe (A), through which a stream of water is kept constantly playing, protects the nozzle of the air-pipe. B is a section of the tuyere, showing the spiral tubing inclosed in cast iron, and C shows the tuyere ready for putting into the furnace. The exact position of the tuyere, and its connexion with the hot-blast apparatus, are shown in fig. 377. Arrangements are usually made for heating the blast of air before it enters the furnace, to the temperature of about 600°, or the melting point of lead. For this purpose the air is made to circulate through a number of pipes which are heated in the small furnace shown to the right of fig. 377. The advantages of the *hot blast*, as it is called, are the saving of fuel, the use of coal instead of coke in the furnace, and the diminished quantity of flux required. When it is considered that not less than six tons weight of air per hour are injected into a blast furnace of ordinary size, the cooling effect

of such an enormous quantity of air must be great; but by heating the air before sending it into the furnace, the saving of fuel has been found to be such, that 2¾ tons of coal are now sufficient for the production of a ton of iron from ore, which would have required eight tons when the cold blast was used. It is stated, however, that hot-blast iron is inferior in tenacity to the cold-blast.

When such a furnace is regularly at work, it is charged at the top at regular intervals with coal or coke, and a proper mixture of roasted ore and of a lime-stone flux, broken into small fragments. When there is a regular incline from the coke-yard or kilns to the tops of the furnaces, the materials are conveyed in loaded barrows (fig. 380), and turned into the furnace-mouth, or they may be accumulated at that elevation, and weighed out in regulated portions; but in a flat country, the charge is weighed out below, and the barrows are drawn up an inclined plane, as in fig. 379.

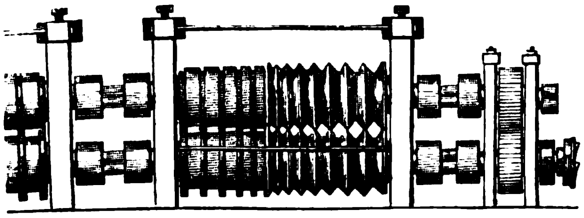
The chemical changes which take place in the furnace are somewhat complicated; but we may here briefly state, that the ore, having been rendered porous by the previous roasting, is readily penetrated by the flame of the ascending gases, and the iron becomes reduced in the upper part of the boshes, where the heat is comparatively moderate. The reduced metal, mixed with the earthy matters of the ore, gradually sinks down to the hotter parts, where the earthy matters melt and unite with the limestone flux into a crude species of glass, consisting principally of the silicates of lime, magnesia, and alumina. In the meantime, the iron in a minutely divided state, coming into contact with the carbon of the fuel unites with a portion of it, and forms the fusible compound known as cast iron. This carbide of iron melts, sinks down below the tuyeres through the vitrified slags, and is protected by them from the further action of the air. The slag exceeds the iron in bulk by five or six times: it floats above the melted metal, and is allowed to flow off as already noticed, whilst the iron is run off at intervals of eight, twelve, or twenty-four hours.

Drawing off the iron, or *casting*, as it is called, is a splendid sight, imperfectly represented in fig. 383. The shed in front of the furnace is covered with sand to the depth of ten or twelve inches, and, previous to casting, a channel called the *sow* is formed in the sand, extending some forty or fifty feet from the furnace: branching off from the sow at right angles, a number of smaller channels called *pigs* are formed. The hole in the bottom of the hearth being tapped, a river of molten metal rolls slowly on, filling up the large channel, and turning aside into the smaller channels. As the moulds become filled, the surface of the molten metal appears to be in rapid motion; innumerable undulations play upon it, together with beautiful variegations of colour, which cannot be described in words. This refers chiefly to the super-carbonated iron known as *No.* 1, *pig iron*. There are usually six kinds of pig iron. *No.* 1. *No.* 2, and *No.* 3 contain carbon in different degrees; No. 3 is also known as *dark grey iron*, and contains less carbon than the other two. The next quality is called *bright* iron, it being lighter and brighter than the other three. A fifth variety is *mottled* iron, the fracture being mottled with grey and white; while the last variety is named *white* iron, from its silvery-white colour.

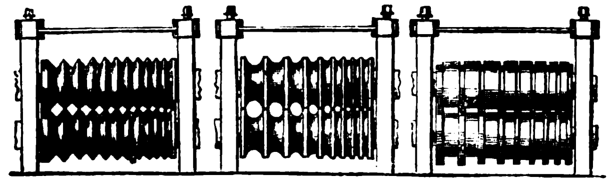
All the varieties of pig iron contain impurities, which render them brittle under the hammer, and unfit for the very numerous appliances of the forge. The impurities consist chiefly of carbon, silicium, and minute portions of sulphur and phosphorus. The carbon and silicium are got rid of by exposing the pig iron to a high temperature under the influence of a blast of air, the effect of which is to convert a portion of the iron into an oxide, which, uniting with the oxidized silicon, forms a fusible slag; the excess of oxide of iron in this slag reacts on the melted metal, and, by giving up a portion of its oxygen to the carbon and the silicon disseminated through the mass, an additional portion of these substances is burnt off. Early in the process a portion of the carbon burns off in the form of carbonic oxide, while portions of sulphur and of phosphorus are also got rid of by oxidation, or accumulate in the slag. The furnace in which this operation is conducted is called a *finery*, or *refinery*, fig. 382, the fire of which is urged by a double row of blast pipes, the nozzles of which are kept cool by the water apparatus already referred to. When the melted iron is sufficiently refined, it is run off into a channel, where it solidifies in the form of a flat cake and it is made brittle by pouring cold water upon it. Coke is the fuel usually employed in the finery; but where a superior iron is required, charcoal is used, the coke containing a portion of sulphur and earthy matters, which injure the quality of the iron.

The refined metal still contains a good deal of carbon and some silicon. To remove these, it is introduced in charges of from four to five hundred-weight into the *puddling furnace*, where it undergoes the operation of puddling. This furnace, represented in section, fig. 392, is what is called a *reverberatory* furnace, the brickwork of the roof being so constructed as to reverberate or reflect the flame of the furnace down upon the charge. The bottom of the furnace is formed of a thick cast-iron plate, protected by a coating of the oxide or cinder formed in previous operations. The chimney is forty or fifty feet high, so as to form a powerful draught, which can be diminished at pleasure by means of a damper. The iron is put in and taken out of the furnace by a large square hole (shown in fig. 387, and also in dotted lines, fig. 392), which, except on such occasions, is closed with a sliding door; at the bottom of this door is a small hole, through which the puddler introduces his tools and inspects his work. The charge, mixed with a proportion of scales of oxide, is first completely fused, then stirred briskly, to mix the oxide with the melted metal, the effect of which is to transfer the oxygen from the oxide to the carbon of the melted metal, and carbonic oxide is formed. This is an inflammable gas burning with a blue flame; its escape produces an appearance of boiling in the metal, and the gas, as it escapes in jets, burns with its characteristic flame. As the carbon diminishes in quantity, the metal becomes less fusible, and at last subsides into a granular sandy mass. The heat is now raised to the utmost; air is excluded from the interior, and the metal soon begins to soften, and to run together, when the puddler gradually collects it into balls, called *blooms*, and subjects each in succession, while still at a glowing heat, to the blows of a massive hammer, called the *helve*, or *shingling hammer*, fig. 389, and also represented, among other operations, in the large engraving fig. 381. This hammer weighs about four tons, and it is lifted by means of a cam, revolving under the nose of the helve. The effect of the blows of this hammer upon the shingle-ball is to squeeze out the liquid slag, to weld the particles of iron together, and to reduce the ball to an oblong shape, fit for the next operation, which is *rolling*. The bloom is still at a bright red heat, when it is passed between a couple of massive rollers (fig. 385), called *puddle-rolls*; the largest hole between the rolls being first used, and the smaller ones in succession, by which means the bloom is rolled out into a bar, or, by passing it between a couple of smooth rollers, into a sheet, as represented in fig. 381. In passing between the rolls, a further portion of the slag is driven off, and the rough bar resulting from these operations is very different in character to the pig iron from which it was produced. The pig iron was hard, crystalline, brittle, and fusible; it is now a long, slender bar of soft, fibrous, tough, malleable iron, fusing with difficulty.

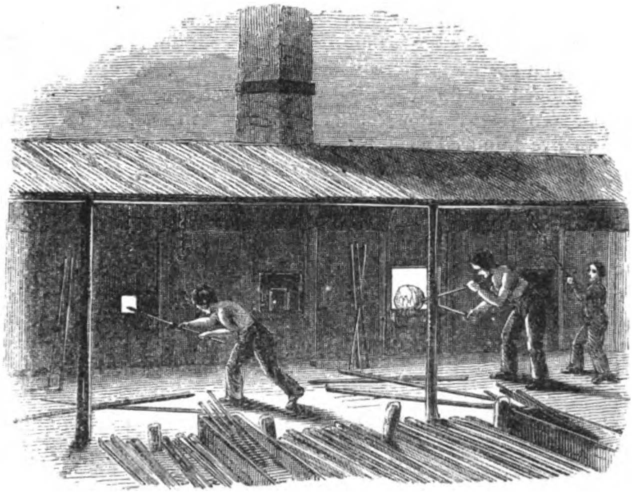
The character of the bar-iron thus produced may be further improved by cutting it up into short lengths by means of powerful shears (fig. 390), and piling several of these pieces upon each other, placing them in a furnace, raising them to a welding heat, and passing them through finer rolls, called the *finishing rolls* (fig. 386). These rolls are of various forms, so as to produce square, round, or flat bars of various sizes. The effect of rolling is to improve the fibre of the iron, and otherwise to exalt the good qualities of the metal. The rolling being complete, the bars are straightened on a long bench of cast iron, then stamped with some letter or foundry mark, and lastly, the rough ends are cut off with the shears.



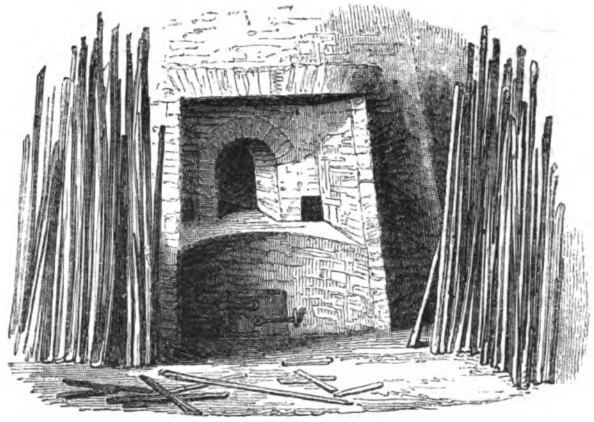
385. PUDDLE BALL ROLLS.



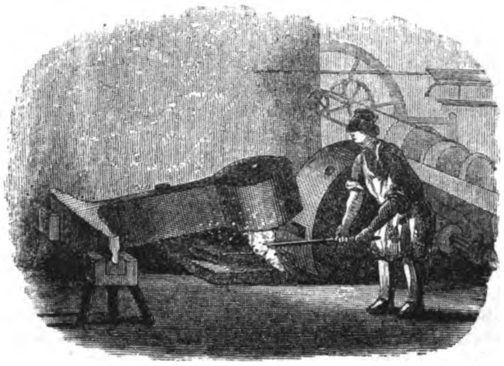
386. FINISHING, OR BAR ROLLS.



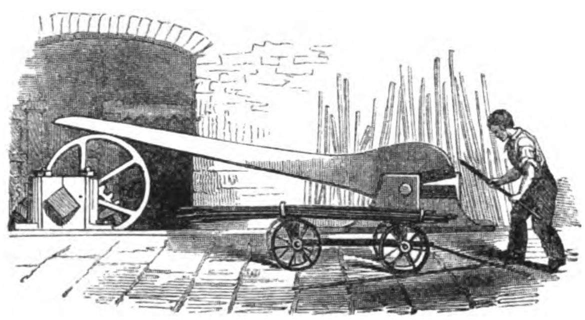
387. PUDDLING.



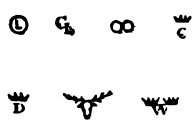
388. MOUTH OF CEMENTING FURNACE.



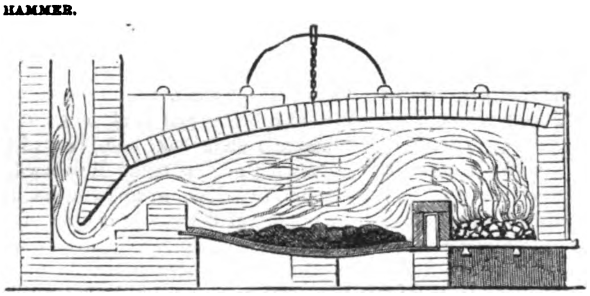
389. THE SHINGLING HAMMER.



390. SHEARS.

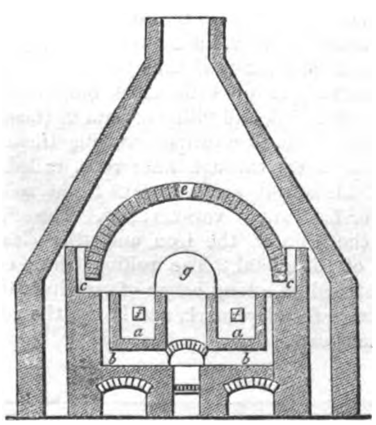


391. OREGRUND IRON MARKS.

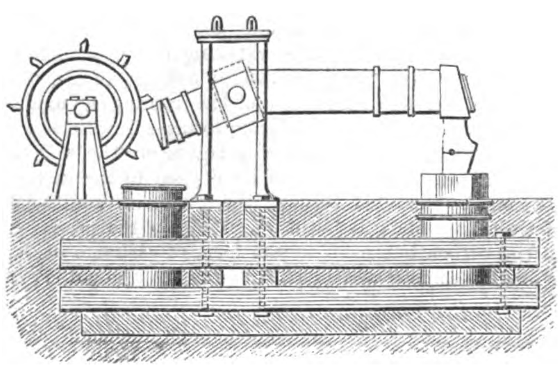


392 SECTION OF PUDDLING FURNACE.

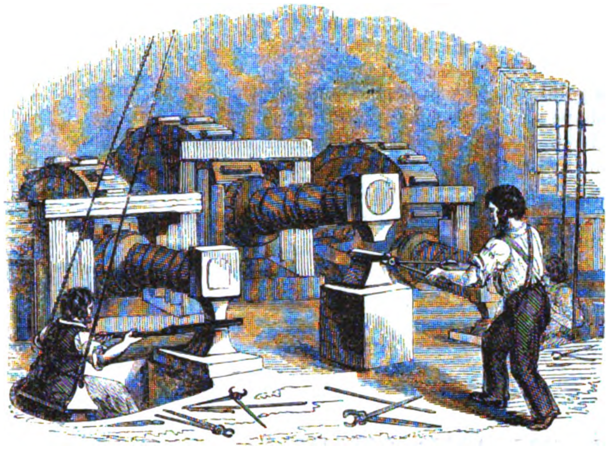
393. FAGGOT.



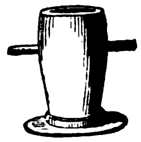
394. SECTION OF CEMENTING FURNACE.



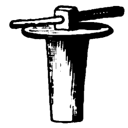
395. TILT HAMMER.



396. TILTING STEEL.

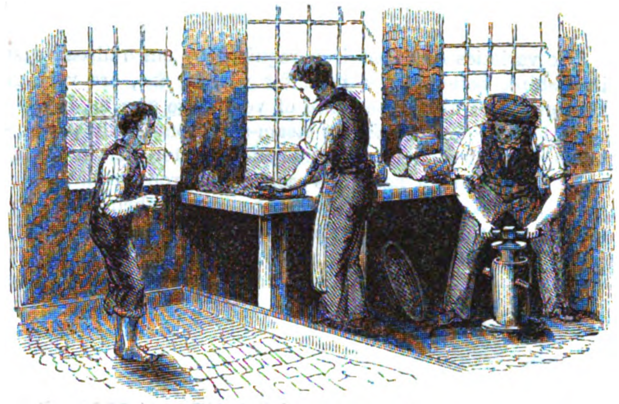


398. MOULD.

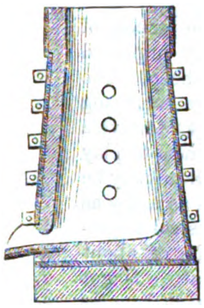


399. CORE.

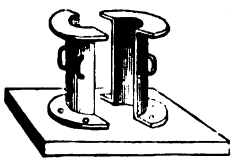
400. CRUCIBLE.



397. PREPARING CRUCIBLES FOR CAST STEEL.



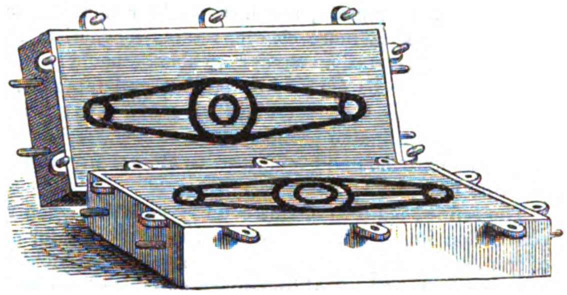
401. SECTION OF CUPOLA.



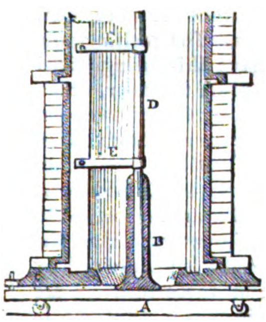
402. PIPE-MOULD.

403. CASTING-POT.

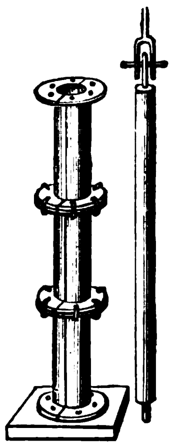
404. DRAWING THE CRUCIBLES.



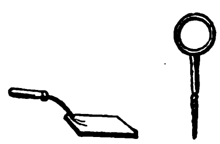
405. FLASK CASTING.



406. SECTION OF MOULD.

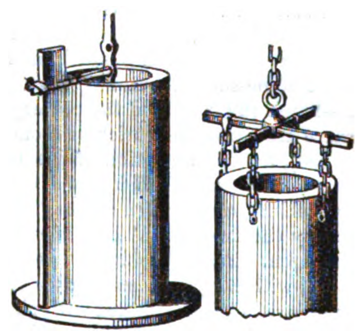


407. PIPE MOULD.

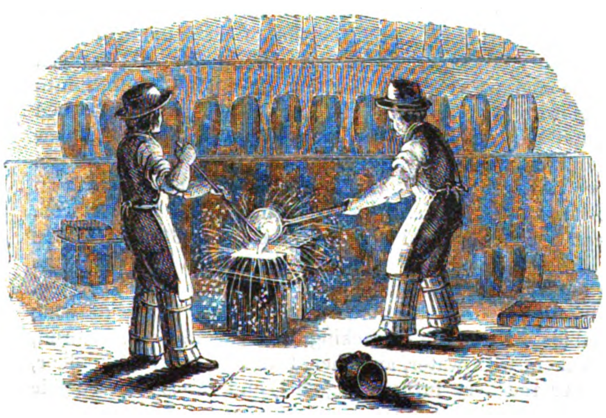


408. TROWEL AND SCREW.

409. RAMMER.



410. CORE.



411. TEAMING.

412. IRON BRIDGE CROSSING THE SEVERN IN COLEBROOK DALE.

The varieties of rolled iron required by our railroad system, iron ships, boiler plates, tires for wheels, &c., are very great. Iron plates require to be rolled of very large size, as, in the construction of the *Great Eastern* steam-ship, some of the plates were twenty-eight feet in length, one and a quarter inch in thickness, weighing two and a half tons each. The iron for plates is prepared by making a pile of rough bars, and, when raised to the welding heat, bringing it under the forge-hammer, where it is beaten into a solid slab, the dimensions of which depend on the weight and shape of the intended plate. It is again heated, and then passed between the smooth rolls, which are at first some way apart, but are gradually screwed closer and closer together. It is brought to the required shape by being passed through the rolls in different directions; and lastly, the ragged and uneven edges are trimmed off with shears.

XXV.—STEEL, AND CASTING IN IRON AND STEEL.

When iron is combined with a smaller proportion of carbon than that contained in cast iron, steel is produced. It is remarkable that a minute portion of carbon, varying from less than one to one and a half parts in one hundred, should confer so many new and valuable properties on iron. It becomes denser than iron, has a finer grain, becomes brighter and whiter in lustre when polished, is more elastic, retains magnetism longer, and does not rust so easily. Steel may also be made so much harder than iron as to be capable of cutting and filing it: steel will scratch the hardest glass, and strike sparks with siliceous stones. But the most valuable property of steel is the facility with which it may be hardened and tempered to almost any degree between extreme hardness and softness.

The refined pig iron of this country is not sufficiently pure for conversion into steel. The hæmatites and other forms of oxide of iron, smelted by a pure fuel, such as charcoal, yield the sort of iron required. Charcoal-iron made at Ulverstone is esteemed; but, perhaps, the best is from the mine of Dannemora in Sweden. Most of the produce of this mine is sent to England, where it is known by the name of *Oregrund* iron, from the port from which it is shipped. This iron is distinguished by one or other of the marks represented in fig. 391, such as the *hoop L*, the *G L*, the *double bullet*, &c. Inferior Swedish iron bears such marks as *C and crown*, *D and crown*, the *Steinbuck*, and *W and crowns.*

Iron is converted into steel in a *cementing-furnace* (figs. 388, 394), a dome-shaped building, surmounted by a hood, as in the glass-house (fig. 276) and the pottery-kiln (fig. 315). Within the furnace are a couple of brick or stone-ware rectangular boxes, *a a* (fig. 394), for the reception of the bars of iron which are to be converted into steel. Below and between the troughs is a grate by which the troughs are heated, the flame being directed round them by the flues *b c*. There is also an opening, *e*, in the middle of the arch. Before the fire is lighted, the bottom of the boxes is covered with a layer of *cement-powder*, as it is called; this consists of powdered charcoal, mixed with about one-tenth of its weight of common salt and wood-ashes. Upon the bottom layer, and at intervals of half an inch, the bars of iron are placed, the spaces between them being filled with the powder; above this is another layer of powder, then another layer of bars; and so on in succession, until the box is nearly full. The remaining space is covered with a layer of damp sand; and the fire being lighted is gradually raised to a full red heat, at which point it is steadily maintained. At the end of each box is a small hole, *f* (fig. 394), called the *tasting-hole*, by which the workman can occasionally draw out a bar to watch the progress of the carburation. In about six or eight days the process is complete; the steel retains the form of the iron, but its surface is covered with *blebs* or blisters, which give it the name of *blistered steel.* Each bar has been penetrated by the carbon; the fibrous texture of the iron has disappeared; so that when broken across it exhibits a fine close-grained texture. It is also rendered more fusible.

The blistered steel undergoes different processes, according to its destined use. To prepare it for forging into edge-tools, it requires to be condensed and rendered uniform by the process of *shearing*, the *shear-steel* thus produced being originally employed for making the shears for cutting off the wool of sheep. The process is also called *tilting*, on account of a tilt-hammer being used. The *tilt-hammer* (figs. 395, 396) is arranged so as to give a rapid succession of blows, by causing the cogs of a wheel to play upon the tail of the helve. In this way the hammer-head may be made to fall with considerable force on the anvil, with as many as from 150 to 160 strokes per minute. The blistered steel is prepared for tilting by breaking the bars into lengths of about eighteen inches, and binding four or more of these into a faggot (fig. 393). This, being raised to a welding heat, is placed under a forge-hammer, similar to fig. 389, which unites the different portions and closes up internal cavities. The rod thus produced being again heated, is passed under the tilt-hammer, the rapid blows of which revive the heat, so that the rod ignites under the strokes. The workman, seated in a kind of swing (fig. 396), advances or recedes with rapidity by a slight motion of his foot, and he quickly converts the rude steel rod into a smooth, sharp-edged prism, which can be forged into shears, edge-tools, and cutting instruments.

The best kinds of cutlery are formed of *cast steel;* that is, the blistered steel, being fused and cast into ingots, becomes more uniform in texture, and of superior quality, from the more equal distribution of carbon throughout the mass. The melting-pots or crucibles are made of Stourbridge fire-clay: this, being mixed with water, is spread out in a shallow trough on the floor, where it is kneaded during several hours by the naked feet of two men (fig. 397). The crucibles are formed in a wooden mould (fig. 398), which being rammed full of clay, the core (fig. 399) is forced into it, when a pot of the form represented in fig. 400 is produced. This is removed from the mould, and placed near the furnace to dry. Each furnace is large enough to contain two crucibles; the fuel is well-made coke, and a powerful draught is maintained by means of a tall chimney. Eight or ten of these furnaces are placed side by side, and they communicate by means of trap-doors with the casting-shed above. The bars of blistered steel are broken into fragments, and the charge for each crucible is weighed out, with the addition of a small portion of black oxide of manganese, which is supposed to improve the quality of the steel. Each pot is charged by means of a long iron funnel, let down into it while glowing with the heat of the furnace. A cover is then put on, and the fire is kept well supplied with fuel. In about four hours the steel is ready for casting: each ingot-mould is about two feet long and two inches square; it is made up of two parts, fitting accurately, and held together by a clamp of iron. It is kept upright by resting against the angles of a pit in the floor. Before putting the parts of the mould together, the interior is smoked over a fire of pitch, to prevent the liquid steel from adhering to or melting the mould. Just before drawing the crucibles, a man puts on sacking leggings and a coarse apron, drenches them with water, and then, throwing up the trap-door, strides over the fiery furnace (fig. 404) and raises the crucible

by means of tongs. A second man immediately removes the cover, while a third grasps the crucible with tongs applied to the side, raises it, and pours the glowing metal into the mould amidst a bright scintillation of sparks (fig. 411); the other man keeping back with a rod any portions of cinder or of slag which may be on the surface. The ingots solidify immediately, and are removed from the mould; while the crucibles are returned to the furnaces for another charge.

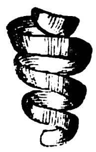
The conversion of iron into various useful forms is brought about by one of two great series of operations, conducted either in the forge or in the foundry. In the forge, pig iron is converted into malleable bar iron, which can be further shaped into different forms by processes which will be noticed hereafter. In the foundry the pig iron is melted and reproduced in various shapes by casting in moulds. In this process it still retains its brittleness, and does not acquire the valuable fibrous texture which allows it to be beaten out under the hammer.

The founder has to mix several qualities of iron, according to the nature of his castings; one piece may require strength and tenacity to bear heavy weights and strains; another must yield readily to the file or the chisel; a third may require to be hard; a fourth to resist sudden changes of temperature; and so on. The mixture of pig iron is melted in a small blast furnace called the *cupola* (fig. 401): this is a cast-iron cylinder, lined with sand or fire-bricks, with openings at various heights in the side for admitting the blast-pipe where it is wanted. Near the bottom is an opening for letting out the liquid metal. The furnace is first filled with ignited coke, and as this begins to sink, alternate charges of coke and pig iron are thrown in every ten or fifteen minutes.

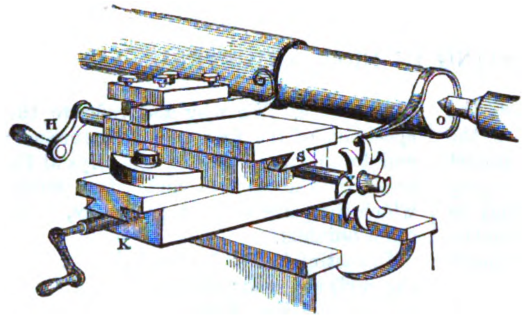
In executing an article in cast iron, a wooden pattern is first made, about one-eighth of an inch per foot larger than the intended object, in order to allow for the contraction of the metal in cooling. There are three varieties of casting:—1st, in moist or green sand; 2d, in dry sand; and 3d, in loam. The first and second methods resemble each other: only the one is intended for fine work, and the other for coarser articles. Green sand is a mixture of fresh sand with about one-twelfth of charcoal, made a little moist, that it may preserve the forms impressed in it. The mould is formed within a couple of iron frames, without tops or bottoms, called *flasks* (fig. 405), furnished with handles for lifting, and with pins and holes for accurately fitting into each other. The lower flask is placed on a board, and is filled with sand well rammed down with a *rammer* (fig. 409). The pattern is then pressed down into the sand until it is half buried, and the sand is smoothed up the sides of the pattern with a small *trowel* (fig. 408). The other flask is now put on, and fine burnt sand or charcoal, called *parting-sand*, is dusted over the surface last prepared to prevent it from adhering to the sand which is now to be put into the upper flask. Channels are also moulded on the lower surface for the introduction of the melted metal. These channels are made by burying some rods of wood, extending from the pattern to the side of the frame. The upper flask is now filled with sand and well rammed down, the rods of wood are removed, the upper flask is lifted off, and the pattern carefully taken out by inserting at each end the point of a screw (fig. 408). Defects in the mould are repaired with sand; and the surfaces being dusted over with fine charcoal, the upper flask is carefully placed in its proper position: and the two being set up on end, the molten metal is brought from the cupola in an iron ladle or pot lined with loam, and is poured into a channel left in the flask for the purpose. The escape of air and of the steam produced by the hot metal is usually facilitated by driving a small iron rod into the sand in various directions from the pattern before the latter is removed. Casting in dry sand is similar in principle to the foregoing. By this method are produced the various pots and pans, ranges, frames for machinery, spandrils for roofs, and similar articles, which do not require a central core. We may also refer to the bridge (fig. 412), as a specimen of the first iron structure of the kind ever erected, and to the iron dome in the Crystal Palace (fig 418), as specimens of the earliest and latest structures in cast iron, in which the parts are cast separately, and put together as in any other building.

In casting hollow tubes, such as water-pipes, the half-cylinders (fig. 402) are used: these are set up on end, and a smooth plug, of the exact size of the intended pipe, being passed through the centre, is supported by a pin passing into a hole in the floor, and is fastened above by the contrivance shown in fig. 407. The intervening space is filled up with moist sand, when a second pair of half-cylinders is added to the first, and sand is rammed in as before; a third pair is added to the second, and more sand added: this completes the length of nine feet, or that of a cast-iron water-pipe. The plug is now carefully withdrawn, and the cylinders, with their lining of sand, removed to the drying-stove. A core is next formed by winding hay or straw round a four-sided bar, and covering it with mortar to the exact size of the intended core, or interior of the water-pipe. When this is solid, the core is drawn out and well dried. The cylinders, with their lining of sand, are now set up in a pit; and the core is carefully adjusted so as to fill up the sand tube, with the exception of a space between the outer surface of the core and the inner surface of the sand, which evidently gives the thickness of the intended pipe. A quantity of molten metal is then poured in so as to fill the space; and when this is cool the mould is hoisted out of the pit, the outer cylinder is removed, the core is taken out, and the pipe, supposing the casting to be perfect, is ready for use. The *casting-pot* (fig. 403) is used for conveying the metal from the cupola; the use of the double handle is for tilting it over in the pouring.

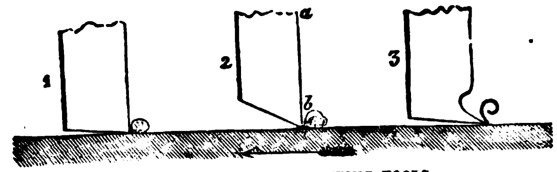
Loam-casting on a large scale, such as the cylinder of a steam-engine, is similar in principle to the method last described, but the details are different. Fig. 406 is the section of a mould for a large cylinder. It is placed upon an iron frame (A), mounted on wheels: in the centre of this frame is fixed a tube (B); C is a ring of iron, with four ears or flanges for the purpose of lifting it; this ring is placed on the frame A, as nearly as possible concentric with the tube B. On this ring a thickness of sand is first placed, and upon the sand a cylinder of brickwork is constructed, clay or wet loam being used instead of mortar. The inner diameter of this cylinder exceeds by a few inches the outer diameter of the intended casting. The inner surface of the brick cylinder is therefore covered with loam, and is made to assume the exact shape of the outer surface of the casting by the following contrivance:—A rod (D), furnished with arms (E), is dropped into the tube B; and to these arms is attached a piece of wood properly shaped, and this, by revolving on its centre D, moulds the wet loam to the shape of the cylinder. This outer mould, now completed, is moved to an oven to be dried, or a fire is kindled within it. The central core of brickwork (fig. 410) is formed in a similar manner; only the outer surface is covered with loam, and made to assume the shape and dimensions of the inner surface of the cylinder by placing the mould-board on the outside. The core is also made dry by being baked: the mould is now lowered into a pit by the cross-piece and chains shown in fig. 410; and when the core is properly adjusted and filled with sand to give it steadiness, a flat cover of dried loam is put over the whole, openings being made in the cover for pouring the metal. Channels are now made in the sand which covers the floor of the casting-house, so as to connect the furnace with the pit; and when everything is prepared, the furnace is tapped, and the metal flows into and occupies the space between the inside of the mould and the outside of the core, forming, in fact, the cylinder required. Letters, figures, &c., in relief, required on the outside of the cylinder, are previously sunk into the loam which forms the inner lining of the mould.



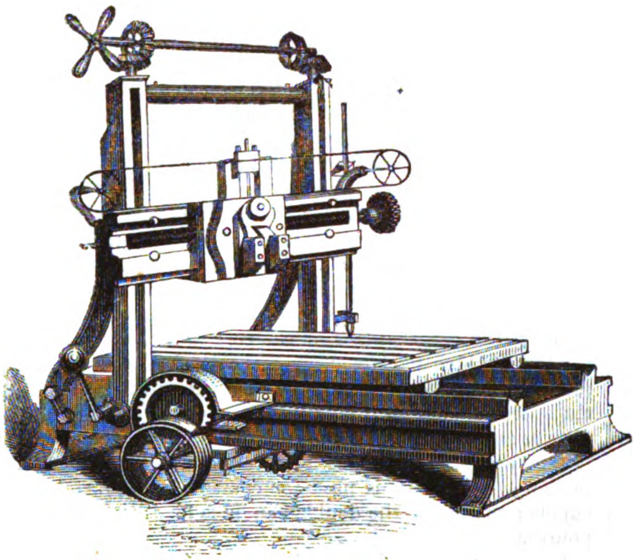
413. IRON SHAVING.



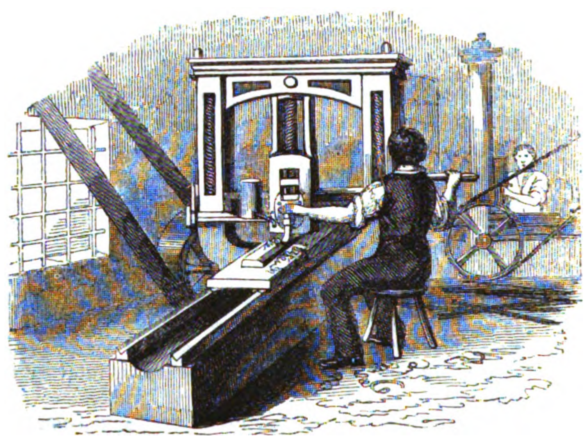
414. THE SLIDE REST.



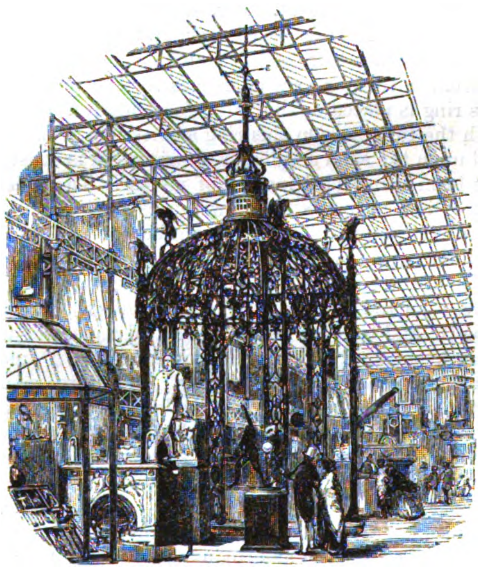
415. BAD AND GOOD CUTTING TOOLS.



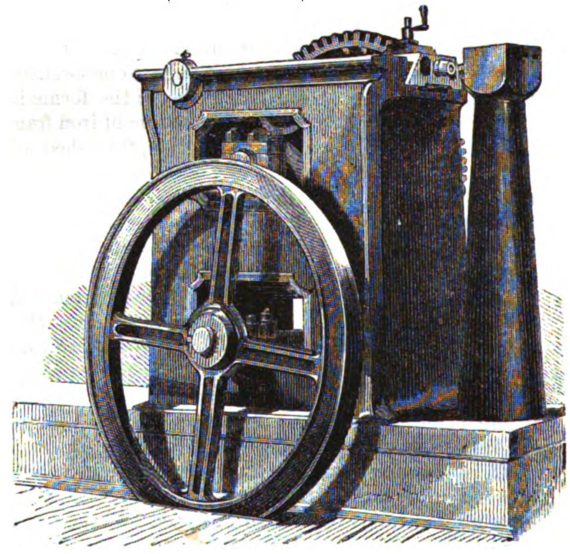
416. PLANING MACHINE



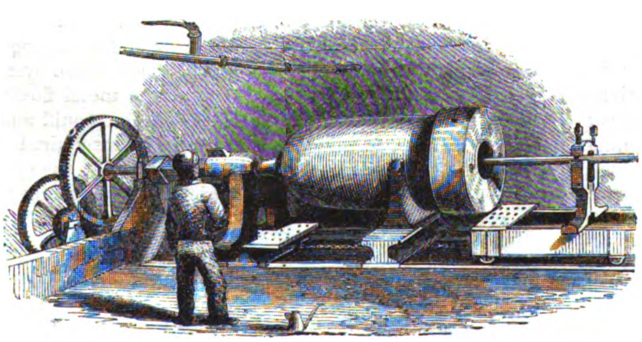
417. PLANING MACHINE.



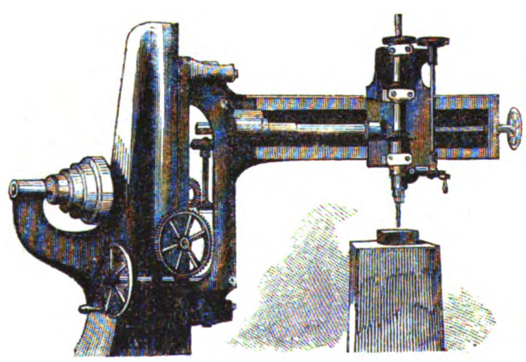
418. THE IRON DOME.



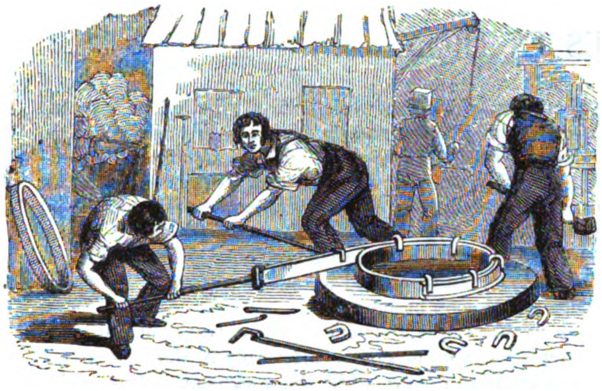
419. RIVETING MACHINE.



420. BORING MACHINE.



421. DRILLING MACHINE.



422. BENDING THE TIRE FOR RAILWAY-CARRIAGE WHEEL.

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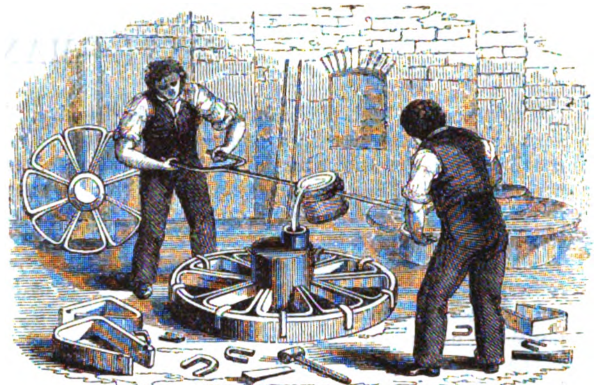
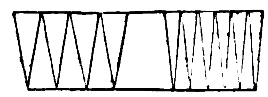
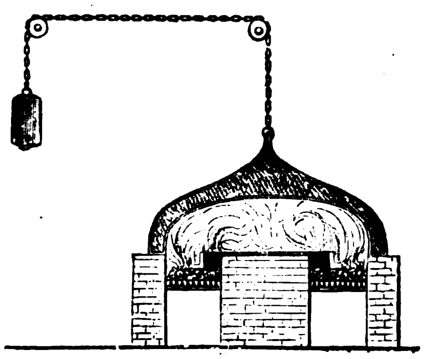


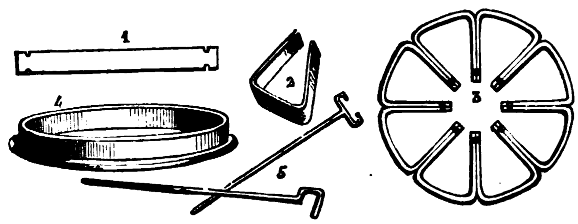
423. CASTING THE NAVE OF RAILWAY-CARRIAGE WHEEL.



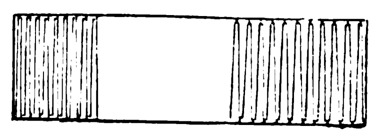
440. ILLUSTRATIONS OF CUT NAILS.



424. RING FURNACE.



425. TOOLS AND SEPARATE PARTS OF WHEEL.

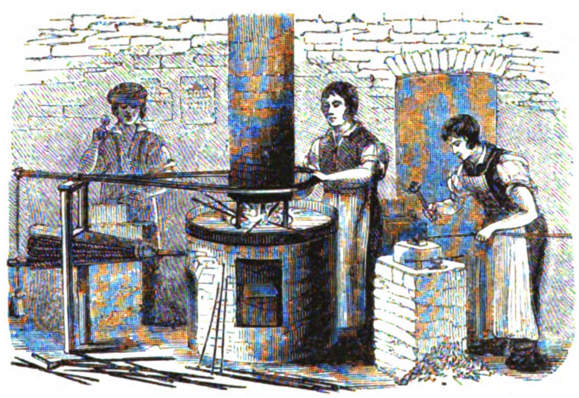


441. CUT NAILS.

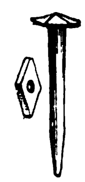
434.

435.

436.



426. NAIL-FORGE.



437.

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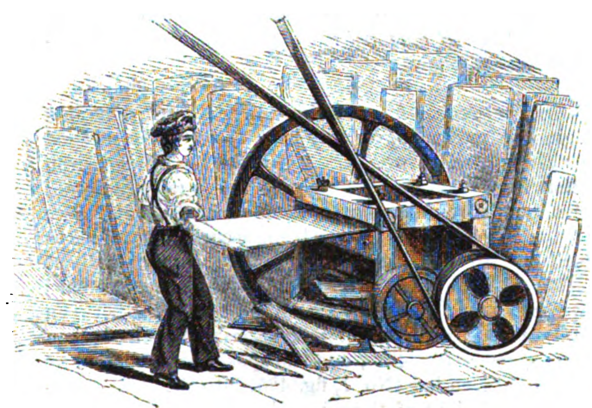
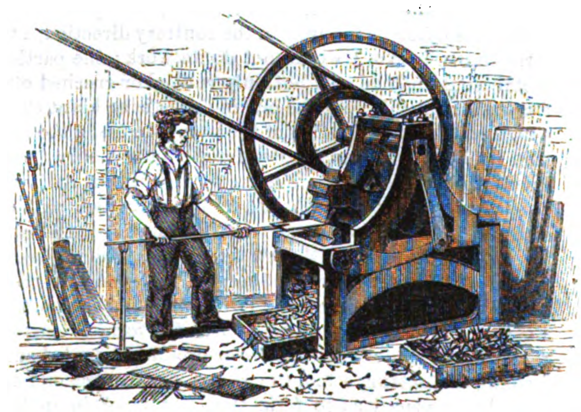
439.



427. PREPARING STRIPS.

428. MOUNTED STRIP.



429. CUTTING NAILS.

XXVI.—MANUFACTURES IN IRON.

The processes, both of the forge and of the foundry, which are such prominent features in an engineer's workshop, are liable to continual variation as new machines and applications of machinery come into use. Thus the railway system, which has not yet been in existence much more than a quarter of a century, has led to the important and extensive profession of railway engineering. The enormous demand for steam-engines, locomotives, rails, and railway carriages has led to the introduction, or at least the improvement, of many powerful machines for turning, planing, punching, drilling, and boring masses of iron with as much facility as the carpenter performs those operations on wood. Few contrivances in the engineer's workshop are more beautiful than the *slide-rest*, fig. 414. Before its introduction, nearly every part of the machine had to be made and finished by manual labour; so that we were dependent on the dexterity of the hand and the accuracy of the eye of the workman for the production of parts of an engine or of a machine, which often require for their efficiency to be exactly of the same shape and size; while single parts were required to be true,—a cylinder, for example, to be really cylindrical, and a plane surface level. The steam-engine owes its present perfection to the means possessed by the engineer of giving to metallic bodies precise geometrical forms. It is evident that we could not have a good steam-engine, if we had not the means of boring out a true cylinder, or turning a true piston-rod, or planing a valve-face.

The slide-rest is an appendage to the turning-lathe, so contrived as to hold a tool firmly to the work; and while cutting a shaving from the bar in the lathe, the tool is slid gently along, and the bar is turned quite true. In fig. 414 the tool is held firmly in a sort of iron hand or vice, which is made to move in the required direction by means of the slide S, the sliding motion being given by the workman, by turning the handle H, while the depth of the cut is regulated by the under-slide K, also moved by a screw-handle. By the separate or combined motion of these two slides, the tool can be made to act along or across the work with great accuracy: the attendance of a workman may even be dispensed with by attaching a star (X) to the wheel (H) and an iron finger to the end of the work in the lathe at O. As the work revolves, the finger will bear down one of the points of the star, the effect of which is the same as turning the screw-handle H, by which the tool is moved along the surface of the work.

In this way cylindrical forms are obtained in metal with great accuracy. The *planing-machine* (figs. 416, 417) is an application of the slide-rest to plane surfaces. In cases of this kind, the form of the cutting-tool is of great importance. If in fig. 415 the shaded portion represent a surface of iron, from which it is desired to cut off shavings, either by moving the iron against the tool in the direction of the arrow, or by moving the tool over the surface of the iron in the contrary direction, a tool of the form shown in No. 1 would not do its work: the particles of the metal would nót be cut, but only rubbed or crushed off by sheer force, since in this case the cutting edge is so blunt that it forms a right angle with the face of the iron. In No. 2 the same objection applies with even greater force; for not only does the tool act at right angles to the surface to be cut, but its form gives it a penetrating action in the direction *a b*, which will produce a number of teeth-like marks. In No. 3, however, the cutting edge is in the direction of the strain or cut, and this edge is also arranged with reference to the greatest strength, the mass of metal behind the edge giving it firmness and support. In such a case the shavings are turned off in the form of curls (fig. 413), without any tendency to *chatter* or produce a rippled surface. In forming and setting a tool to cut any surface, the end of the tool must be so placed as to form the least possible angle with the surface to be cut.

In the planing machine the work is firmly bolted to a table, sliding in dove-tail grooves, and travelling backwards and forwards under the cutting-tool, which admits of accurate adjustment. When one end of the work has escaped from under the tool, the table is moved back, and the slide-rest is moved a little way across the table so as to take off the next shaving close to the one previously cut. It is necessary to keep the tool cool during the work, by allowing cold water to drip upon it, otherwise the edge would soon become soft.

The *boring machine* (fig. 420) is another contrivance of a similar kind. Boring is but a branch of turning, only in the former the tool is usually made to revolve while the work is at rest, while in the latter the work revolves while the tool is at rest. There are, however, exceptions to this: in boring cannon, which are cast solid, the gun is made to revolve, while the borer advances on a fixed axis, or in heavy ordnance the gun may be fixed while the cutter revolves. The arrangement in fig. 420 represents the boring of one of the cylinders of the hydraulic press, by which the Britannia Tubular Bridge was raised. In boring the cylinders of steam-engines, the working-barrels of large pumps, &c., the cylinder is cast hollow, and the cutters are arranged round the rim of a cutter-head of cast iron, attached to a tube, accurately fitted on an axis, and moved through the cylinder by machinery in such a way that sixty turns of the axis may cut one inch of the cylinder.

In making the boilers of steam-engines and other structures in which sheets of iron are held together by bolts or rivets, which, being inserted red-hot into holes, pass through the overlapping edges of the iron plates, the hot bolt is crushed up by means of powerful hammers, amidst a deafening noise and a large amount of labour. In Mr. Fairbairn's *riveting machine*, fig. 419, the work is done by an almost instantaneous pressure, and without any noise. In this machine the boiler or other work is suspended between a die on the upright post; when a moving slide and die, worked by the action of a revolving cam upon an elbow-joint, closes the work and finishes the rivet. By this machine the cylinder of an ordinary locomotive engine boiler, eight feet six inches long and three feet diameter, can be riveted and the plates completely fitted in four hours; whilst to execute the same work by hand would require twenty hours. The *drilling machine*, fig. 421, is a contrivance for giving rotatory motion to a drill; and by means of spur gear, connected with the arm, moving the tool to and fro, or up and down. It is used for drilling holes in metals where accuracy is required, the rougher work being done by the punching machine.

We can do no more in this place than just name such important engineering tools as the *steam hammer*, the *self-acting slotting and shaping machine*, the *drilling and boring machine*, the *punching and shearing machine*, the *bolt-head and nut-shaping machine*, the *wheel-cutting and dividing machine*.

Railway-carriage wheels.—As a specimen of the work done in a railway engineer's workshop, we may here describe the method of making railway-carriage wheels. A straight bar of *angle* iron (rolled so that its section forms a right angle) is raised to a red heat, and then curved round a circular maundril by the contrivance shown in fig. 422: one end of the bar being secured by a staple to the maundril, the bar is bent round by levers, shown separately at No. 5, fig. 425, and also with the assistance of a sledge hammer; and the two extremities of the bar are united by driving between them a couple of wedges of iron at a welding heat. The tire is then put into a *ring-furnace* (fig. 424), and the spokes are prepared by bending a wrought-iron bar (No. 1, fig. 425) into the form represented at No. 2, and eight of these bent bars are arranged into a complete set of spokes, as in No. 3. These are all united by the

nave, which is cast solid, for which purpose the spokes are fixed within a maundril, as in fig. 423, their centres terminating in flasks, in which the proper shape of the nave has been moulded. Molten metal is poured in, after which the spokes and nave are inserted within the tire, which is too small for the purpose until it has been heated and stretched; for which purpose the tire is taken out of the ring-furnace, and placed, while still hot, in a *stretching machine*, in which a number of blocks, forming segments of the circle required, are thrust out by means of a hydraulic press so as to stretch the hot tire sufficiently to allow the arrangement of spokes and nave to drop in. This being done, the tire is left to cool, and in doing so closes in upon the spokes, binding and compressing them firmly; the whole being finished by a rivet through each spoke into the tire.

Nails.—When William Hutton, the historian of Birmingham, in the year 1741, first approached that city from Walsall, he was surprised at the prodigious number of blacksmiths' shops upon the road; and could not imagine how the country, though populous, could support so many people of the same occupation. In some of these shops females were observed wielding the hammer; and being struck with the novelty, Hutton inquired whether the ladies in that country shod horses? He was told, with a smile, that they were *nailers.*

Such was the condition of most of the useful arts in this country, in the middle of the last century. Articles in common every-day use were produced by individual efforts, or handicrafts. As the demand for any particular article increased, and the supply did not keep pace with the demand, wages rose, and the trade was said to be flourishing. But as the religious and mental culture of the workman, if attended to at all, did not keep pace with his worldly prosperity, he was accustomed to spend his gains in carrying his so-called pleasures to excess; and, though earning good wages, his wife and children seldom shared in the prosperity. In the case of the nailer, as the husband would not work longer than he was compelled to do, his wife and daughters, easily acquiring the simple art, would continue the exertion until enough had been earned to pay the week's expenses. The nailers, never dreaming of being competed with by machinery, dictated their own prices; or, working under one master, would strike for higher wages, until at length, by the slow but accumulating effect of many different circumstances, machinery, in this as in so many other cases, came to perform the work of men's hands. For many a long year did the nailer continue to struggle against the machine; and the wife and daughter, who had formerly learned the occupation from choice, continued to exercise it from hard necessity; wages fell lower and lower, until at length the nailer's trade came to be one of the lowest and most despised. Some descriptions of nails are still made by hand; but the great bulk of those for which there is most demand are easily and cheaply cut out of sheets of metal by machinery.

Nails are forged by hand from rods of wrought iron of suitable size. There are not less than 300 different sorts of nails, with at least ten different sizes of each sort. The nailer's apparatus consists of a small hearth or forge, for bringing the iron to a proper heat, an anvil, a hammer, and one or two other tools. The forge represented in fig. 426 is of an improved kind, but does not require particular description. The nailer begins work by putting the ends of three or four nail-rods into the fire, and working the bellows to bring them to the proper heat. He next takes one of the rods out of the fire, and resting it on the anvil, forges or *draws out* the nail by a few skilful blows, and cuts it off from the rod by means of a chisel called a *hack-iron.* If the nails are of moderate size, the end of the rod is still sufficiently hot to allow another nail to be forged from it, before returning it to the fire. The next operation is to form the heads of the nails cut off: this is done by a tool called the *bore;* this is a piece of iron, furnished at each end with a steel knob, perforated to the size of the shank or hollow of the nail, and countersunk so as to correspond with the head. Taking up a nail while very hot with a pair of tweezers, and inserting its point downwards into the bore, the nailer strikes it with a hammer upon the projecting end, which forces it to take the shape of the perforation.

Some of the principal forms of nails are represented in figs. 430—439. Fig. 430 is called *rose-sharp,* and is much used for coopering, fencing, and other coarse purposes, where hard wood is used. A thinner sort, called *fine-rose,* is used in pine and other soft woods, the broad-spreading heads serving to hold the work down. Fig. 431 is the *rose,* with *flat* or *chisel* points, which, being driven with the edge across the grain, prevents the wood from splitting. Fig. 432 is the *clasp*-nail, from the form of the head, sticking into the wood and clasping it together: it is much used by house-carpenters. *Clout*-nails (fig. 433) are used for nailing iron-work and various substances to wood: the *counter-clout* (fig. 434) is countersunk under the head, and has a chisel point. Fig. 435 is called *fine-dog,* to distinguish it from a thicker nail, called *strong* or *weighty-dog.* Fig. 436 is known as the *Kent hurdle;* fig. 437 is the *rose-clench,* used in ship and boat-building: it is called clench from the method of hammering down or clenching the end over a small diamond-shaped plate of metal, called a *rove. Horse*-nails are made so that their heads may lie flush in the groove made for them in the horse's shoe. *Brads* (fig. 439) form a large class of useful nails, a remark which also applies to *tacks.*

It is easy to see that nails or brads in the form of simple wedges can easily be cut from a strip of iron, as in fig. 440; where the stronger sections represent that form of shoe-nail, called a *sparrable* or *sparrow-bill,* from its resemblance to the mandible of a familiar bird, the slighter sections in the same figure being named *sprigs.* By a little contrivance, it is not difficult to cut both brads and headed nails out of a flat strip of metal without any waste; as will be seen by reference to fig. 441, all that is necessary being to turn over the strip after each cut, so as to make the heads and points of contiguous nails fit into each other.

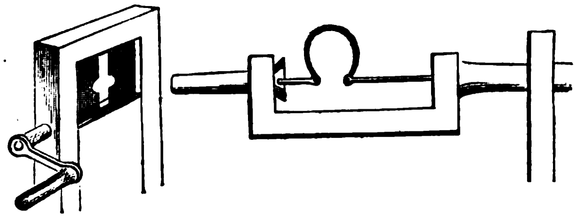
The iron from which nails are cut, is in the form of sheets or plates of the proper thickness: these sheets are cut into strips of the required size, by means of a powerful *cutting-press,* fig. 427. Each of these strips is then mounted on a rod (fig. 428), and is held in the *nail-cutting machine* (fig. 429), the further end of the rod being supported on a forked rest in order to keep the strip in a proper position. The nail-cutting machine contains a couple of steel dies, or a punch and a die, by which a nail is cut off whenever the strip is presented; but as every cut leaves the end of the metal oblique, in consequence of the shape of the nail, the strip must be turned over after every stroke. The machine works with great rapidity, often making as many as 160 strokes in a minute. There are several forms of the nail-cutting machines: in one of them, after the nail is cut off from the strip, it is caught by a clasp, and exposed to a strong pressure, whereby a head is produced much in the same way as in the operation of forging.

Machine-made nails require to be annealed: the strong compression to which the iron has been subjected in rolling and in cutting and punching, hardens the metal so as to produce an amount of brittleness which requires to be removed: this is done by putting the nails into close iron boxes, heating them in ovens, and allowing them to cool gradually: they are lastly packed in strong hempen bags, or are made up in bundles or in casks, according to the market for which they are destined.

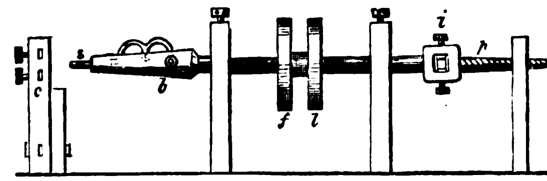
Screws.—The screw, also called the *screw-nail,* but more commonly the *wood-screw,* from its use by carpenters for fastening pieces of wood, or of wood and metal together, is a neater fastening than a nail, and is used in many cases where a hammer could not be applied.

Blanks for screws were formerly forged by the nailers; but screw-making has long since passed into a factory operation, and as such we shall describe it.

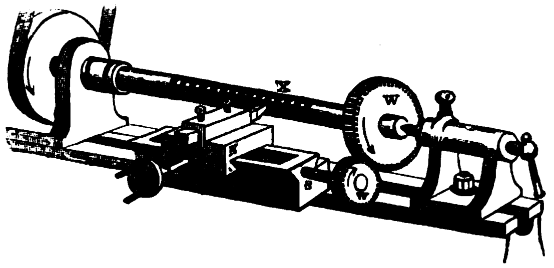
In making screws of the most common sizes, a coil of wire is arranged so that it can be drawn into the blank-making machine



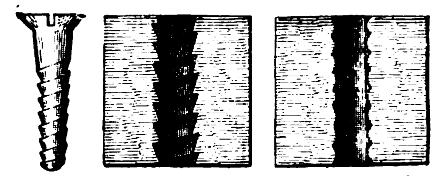
442. ARRANGEMENT OF DIES FOR SCREW-CUTTING.



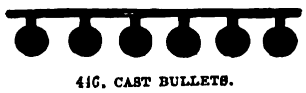
443. ARRANGEMENT OF LATHE FOR SCREW-CUTTING.



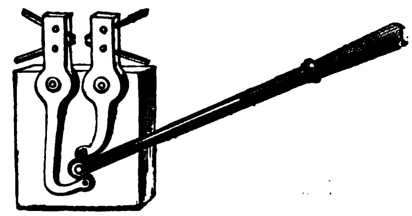
444. SCREW-CUTTING MACHINE.



445. FORMS OF WORM.

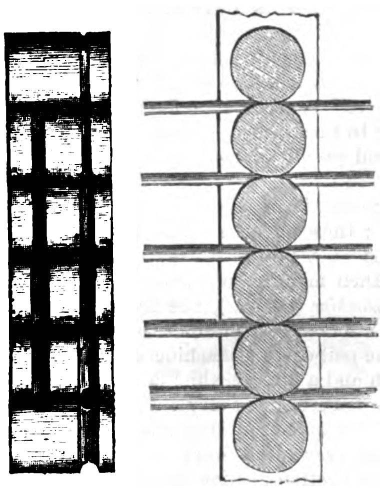


446. CAST BULLETS.

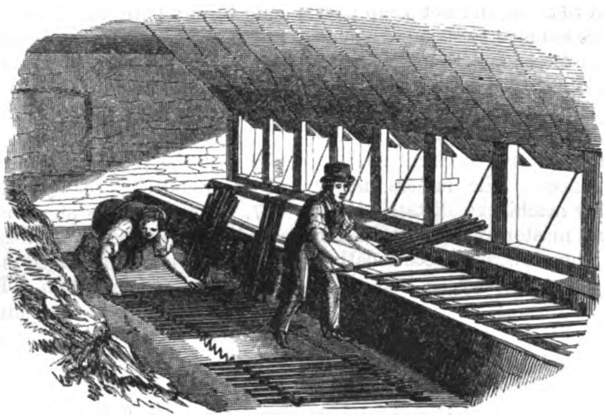


447. SCREW CUTTERS.

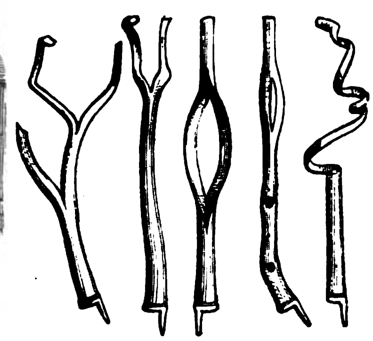
448. TWISTED BARREL.



449. STEEL ROLLERS.

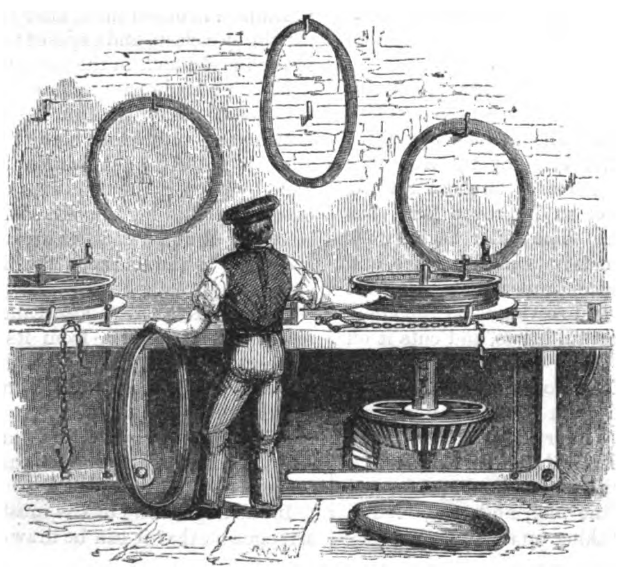


450. INTERIOR OF PROOF-HOUSE.



451. GUN-BARRELS BURST IN PROVING.

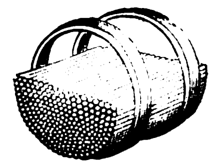
452. CUTTING THE NICK.



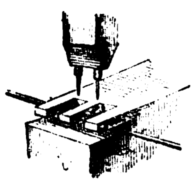
453. WIRE-DRAWING.

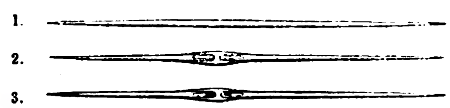
454. CUTTING THE WORM.


455. CUTTING THE WIRE INTO LENGTHS.

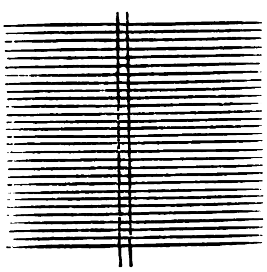

456. STRAIGHTENING RINGS

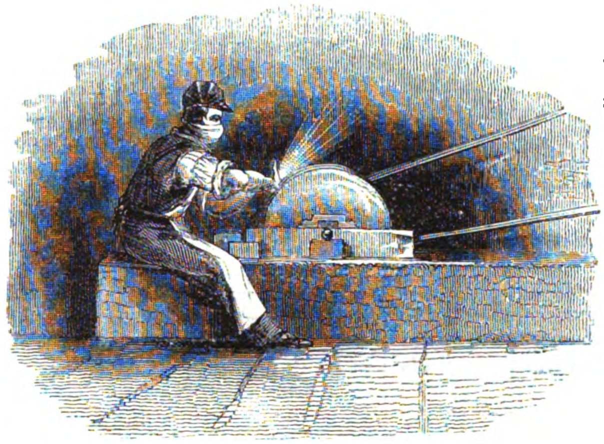

457. STRAIGHTENING THE WIRE.

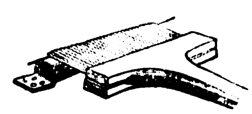

459. EYEING.

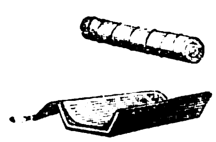


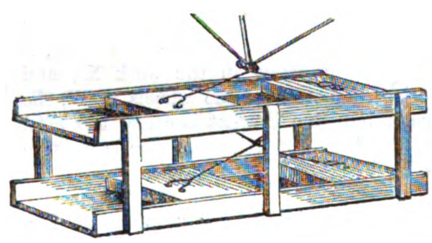
461. COMMENCEMENT OF EYEING.


460. SPITTED LENGTHS.

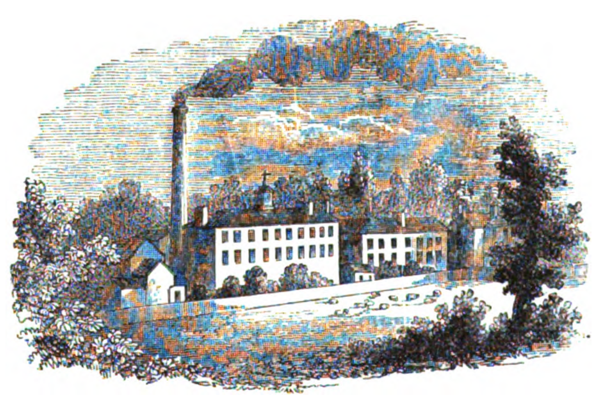

458. POINTING THE NEEDLES BY DRY GRINDING.


462. HEADING.


463. MAKING UP BUNDLE.


464. SCOURING MACHINE.


465. DRILLING AND POLISHING.


466. THE BRITISH NEEDLE-MILLS, REDDITCH.

as it is wanted. Pieces of the proper length are cut off; one end of each is struck up to form the head, and the blanks thus produced are turned out into a box. The blanks are placed separately in a lathe, and the heads and necks are properly shaped by turning. Next, the notch or nick in the head of the screw is cut by a circular saw (fig. 452). A woman puts each blank into a metal clasp, and by means of a lever raises it to the cutter; then opens the clasp, when the blank falls out, and she inserts another in its place: this is done with great rapidity. The next operation is *worming*, or cutting the thread, which is also done in a lathe; the nick just formed assisting in holding it steadily therein. Fig. 443 shows the arrangement of the lathe:—a steel spindle revolves by the motion of a strap passing round the fast-pulley *f*; *l* being a loose pulley, to which the strap is shifted when it is required to stop the machine. At *i* is an iron box for holding the regulating screw (*p*), which is an exact pattern of the thread of the screw to be cut. The blank *s* is fixed in an iron cheek (*b*), and is held by the chisel spike of a hasp, entering the nick of the blank. The cutters are arranged in the frames at *c*, and are shown on a larger scale in fig. 447. The frames move on joint pins, so that by the action of a lever the cutters can be made to act on the shank of the blank with any required amount of pressure. There is also a lever, which causes certain directing points resembling the cutters to close upon the regulating screw *p*; and the two levers being connected by a horizontal bar, the cutters and the directors can be applied at the same moment; so that while the inclination of the thread is determined by the pattern screw, its shape is given by the form and position of the cutters fig. 447. *Gimlet-pointed screws* are cut by means of dies (fig. 442) instead of cutters. The dies are opened and shut by a right and left handed screw; and as the dies regulate the size of the thread, a pattern screw is not required. The form of the worm is of importance to the efficiency of the screw, as will be evident by comparing the new with the old form in fig. 445. The first figure represents the screw, the second the mould made by it in wood, while the third is a section of the common form of screw, in which the worm is shallow and imperfect.

The large iron screws, used in vices, presses, &c., are cut by the *screw-cutting machine* (fig. 444), which consists of a slide rest, in which the tool-holder is slid along by means of the guide-screw S, which receives its motion from the work in the lathe by means of the wheels W W. As the tool-holder slides along, it must evidently leave a spiral or screw in the work X; and according to the respective diameters of the wheels W W, the screw on X will be more or less fine in what is called the *pitch* of the thread, according to the proportions of the respective diameters of the wheels W W.

Gun-barrels.—Gun-barrels are made in large numbers at Birmingham. The iron is fagoted, hammered, flattened out between rollers, and clipped with shears into a plate or *skelp* of the proper size for a gun-barrel: this is then moulded into shape over an iron maundril, so as to form a compact tube of iron. A strike among the skelp-welders, some years ago, led to a method of welding gun-barrels by rollers. The plan consisted in turning a bar of iron, about a foot long, into the form of a cylinder, with the edges a little overlapping. This was raised to a welding heat; and a cylinder of iron being placed in it, it was passed quickly between a couple of rollers: the welding was thus performed with a single heating, and the remainder of the elongation required to bring it to the proper length was performed in a similar manner, but at a lower temperature.

Barrels for fowling-pieces are known as *stub*, *stub-twist*, *wire-twist*, *Damascus-twist*, *stub-Damascus*, and some others. Stub iron is formed from old horse-shoe nails called *stubs*, a form of iron which owes many of its good qualities to its repeated workings. The stubs are packed closely together, bound by means of an iron hoop into a ball, raised to a welding heat, united by hammering, and drawn out into bars of convenient length; or the stubs may be mixed with a portion of steel and be puddled, and after welding into a long square block, may be drawn out by a tilt hammer (fig. 395) into rods of the proper size. Stub-barrels are also formed from scrap iron, which consists of the cuttings and waste of various manufactories. This is sorted, and iron of various qualities is prepared from it, such as *wire-twist*, *Damascus-twist*, *stub-twist*, &c. For twisted barrels, the iron is drawn out into ribbons, and these are twisted, while red-hot, over an iron rod, fig. 448: the welding of the edges being completed by *jumping*, that is, striking the spiral forcibly on the ground, and also by hammering.

After the barrel has been forged, it is bored: the exterior is turned in a lathe; and the barrel, having been made equal and quite correct in every part, is tapped or screwed at the breach end, and the plug is fitted. The barrel is next *proved* by giving it a charge of gunpowder three or four times greater than it will afterwards have to bear, and a bullet is also added. The bullets are cast by pouring lead into a long mould, which, when opened, produces them in the form shown in fig. 446; but they are separated from the pipe and stem with a pair of nippers with cutting edges, adapted to the surface of the bullet. The barrels being thus prepared, are arranged on frames in a low shed, fig. 450, to the number of about 130, in two rows, one above the other. The shutters being closed, the barrels are fired by means of a train; and the bullets are received into a mass of sand placed against a dead wall. The barrels that pass well through this ordeal are stamped with the mark of the Birmingham Proof-House; but those which are burst are of course returned as useless. Fig. 451 represents a number of specimens of barrels burst in proving.

Wire-drawing.—The process of drawing out a length of wire from a short thick rod is a gradual one. The rods are reduced in size by passing them repeatedly through rollers, one arrangement for which is shown in fig. 449; in which the rod of iron or of steel, having passed between the first and second rollers from the bottom, the end is caught by a man on the other side, with a pair of tongs, and pushed back between the second and third rollers: it is then passed between the third and fourth, and is further reduced between the fifth and sixth. The rods are made up in coils for the wire-drawer, who removes scales of rust from them by putting them into a revolving cylinder with coarse gravel and water. The rod is then forcibly dragged through a hole in a piece of hard steel called a *draw-plate;* and as this hole is a little smaller than the wire, the latter must yield and become extended in length: this lengthened wire is again passed through a hole smaller than itself, whereby it is again drawn out, and so on for ten, twenty, or thirty holes, all gradually diminishing in diameter until the proper size is obtained. Fig. 453 represents the factory arrangement for wire-drawing. The draw-plate is fixed in a bench, and by the side of it is a short cylinder or drawing-block, the rotation of which draws the wire through the plate, and winds it on the rim of the block. Motion is given to this block by means of a horizontal shaft, containing a mitre or bevel wheel, which drives the upright shaft, containing the block. Each block can be stopped in a moment by pressing a lever with the foot, whereby the block is lifted off its upright axis. After the rod has been drawn out a few times, the metal is so hard, by the forcible compression of its fibres, as to require softening before the drawing can be continued. The wire is therefore made up in coils, placed in cylindrical boxes, raised to a red heat, and allowed to cool gradually. This operation may have to be repeated several times during the drawing; and after each softening, the wire must be cleansed by being pickled in dilute sulphuric acid. It is also usual to place the coil at the draw-bench in a tub of starch water, or stale beer grounds. This enables the wire to pass more easily through the draw-plate, and also has the effect of giving a clear bright colour to the wire.

Needles.—The manufacture of these small but most useful articles includes a number of minute but interesting processes,

and affords a good illustration of the valuable principle of the division of labour. That a large factory, such as that represented in fig. 466, should be devoted almost entirely to the production of needles may well excite surprise; but there is more cause for admiration in the fact, that the Worcestershire village in which it is situated contains a number of needle factories; that the whole population of the village is directly or indirectly concerned in the production of needles; that many of the processes are conducted in the cottages of the villagers, and further, that this absorption of the faculties of a whole village is not confined to Redditch, but applies also to Feckenham, Bexley, Studley, Coughton, Alcester, Astwood Bank, Crabb's Cross, and some other villages, all of which lie near together. Some years ago, when the writer visited Redditch, he was informed that the weekly production of needles in that village amounted to 70,000,000. The increasing population of Great Britain, and the fact, as we hope it is, that very few females in the land are unskilled in the use of the needle; the demands of our colonies and of foreign countries for British needles, may well entitle us to believe the statement that, at the present time, upwards of 10,000 persons are directly concerned in the manufacture of these tiny articles.

The wire for good needles is not *mill-drawn*, as described above, because by such means the surface of the wire is not sufficiently smooth nor the gauge or thickness of the wire sufficiently regular; but the wire is *hand-drawn*, in which case the man attends to one drum instead of to several drums; and should the wire *rip* or *tear*, the drawer can feel it, and remove the damaged wire. Besides this, after each softening, the use of sulphuric acid is avoided; the scale being removed by means of rubbers covered with emery and oil.

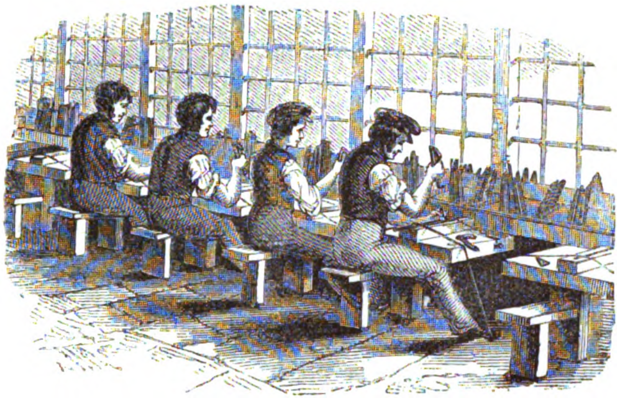
The first process in needle-making is to cut the wire into lengths by means of shears, fig. 455; each length being sufficient for the making of two needles. In the needles known as No. 6, each piece is about three inches long, and as many as 30,000 pieces form one batch. The lengths thus produced partake of the bend of the coils from which they were cut. The second process is to straighten the wires; for which purpose many thousand lengths are placed within a couple of rings, fig. 456, and are thus conveyed to a furnace, where they are heated to redness and then allowed to cool slowly. This softens the wires and admits of their being straightened by mutual friction, for which purpose a tool called a *smooth file* is placed between the two rings (fig. 457), and rubbed briskly backwards and forwards, when the motion of the lengths upon each other effectually straightens them.

The third process is pointing, or grinding the ends of the wires on a grit stone (fig. 458). Several thousand wires can be pointed at both ends in an hour. A stream of sparks accompanies the contact of the wires and the stone, and minute particles of grit and steel fill the air of the room, and, entering the workman's lungs, produce a disease called the "grinder's asthma." The only effectual remedy for this is to box in the stone, and connect it with a channel passing out into the open air, and so to rarefy the air in this channel by means of a revolving fan, that the air of the workshop shall always tend to move in a current, and blow downwards upon the stone so as to convey the metallic and stony dust into the shaft. The stones for the dry grinding of cutlery (fig. 479) are arranged on this plan with wonderful benefit to the health of the workman.

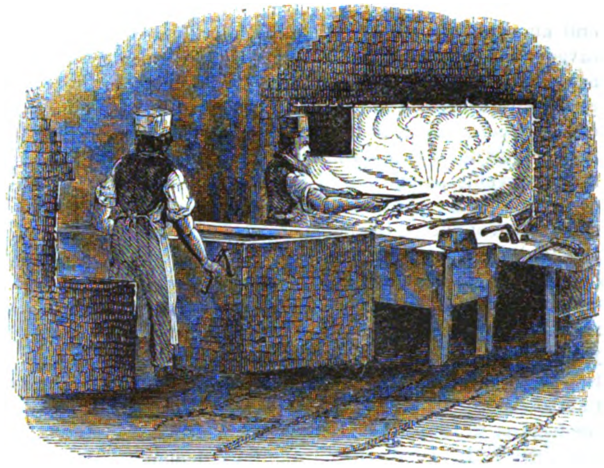
The next process is to flatten out the centre of each wire, by means of a pair of dies and a stamp, so as to form the shape of two eyes, the ring of the eye being less indented than the other portion. Fig. 461 will show the progress of *eyeing*. No. 1 is the wire pointed at both ends; No. 2 represents the groove or *gutter*, which is useful to guide the thread in threading a needle. A spot is also indented where the eye is intended to be. The eyes are next pierced through by means of a couple of steel points (fig. 459), when the wire is in the condition of No. 3, fig. 461. If it were attempted to flatten out the wire and perforate it at one operation, the metal would be torn and otherwise injured. The next operation is to remove the bur or projecting line of metal on each side of the eyes. For the sake of expedition, a number of lengths are spitted on two wires (fig. 460), and the burs are removed by means of a flat file. The lengths are next separated into two portions, by bending the soft wire backwards and forwards between the two spits. The points of each row of needles are then grasped in a kind of hand-vice or *clam*, as shown in fig. 462; and the heads, being placed on a raised piece of metal, are filed into shape. The needles are now said to be *headed* or *made;* not that they are by any means finished, but they are complete so far as regards the length, the point, the eye, and the head.

The foregoing details include the *soft work*, as it is called. Preparatory to the *bright work*, the needles go to the *soft-straightener*, who rolls them upon a flat steel plate with the convex face of a smooth steel file. The next process is *hardening*, for which purpose the needles are raised to a red heat and are suddenly cooled by being quenched in cold water or oil. This makes them hard and brittle. Some of their hardness is removed by *tempering* on a hot iron plate; and when a blue film begins to form upon their surface, they are then said to be of the proper temper. The action of heat has been to distort the needles more or less; and the next process is *hard* or *hammer-straightening*, in which each needle is tapped with a small hammer upon an anvil. The anvil is a smooth plate of steel, upon which the needles are rolled with the finger; and such as are not quite straight are immediately detected and corrected. This work is commonly done by women in their own cottages. Then comes the operation of *scouring* or *cleaning*. From 40,000 to 50,000 needles are made up in a bundle by first placing a piece of canvas in a tray, fig. 463, and then arranging the needles in heaps in the direction of their length. Emery, oil, and soft soap are sprinkled on the needles, and they are rolled up in the canvas, and formed into the cylinder shown in fig. 463, by tying with string. A couple of such rolls are placed in the *scouring-machine*, fig. 464, which consists of weighted slabs or rubbers, which roll the bundles of needles backwards and forwards; and this friction is kept up for fifty or sixty hours, the effect of which is to make the needles rub over and over each other; and this, with the assistance of the oil, emery, &c., produces that smooth bright surface which is essential to the useful action of a needle. The canvas wrapper of the needles wears out under the friction; so that after about eight hours' rubbing the needles are unpacked, washed in soap and water, and packed up again with a mixture of putty-powder and oil. They are then placed in the scouring-machine for another eight hours; and this process is repeated, for the best needles, five or six times. There is no better method of polishing than this, although it leads to a considerable amount of breakage.

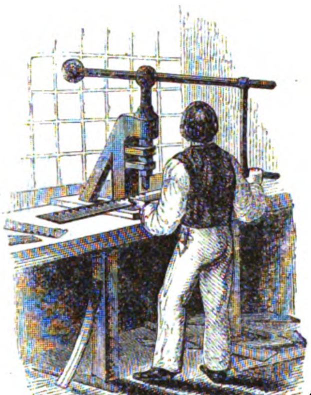
The needles are next passed into the *bright-shop*, where they are collected in trays, and arranged with the points all the same way: this is done by placing the needles in heaps, and pressing the ends against the flat of the hand by means of the fore-finger, which is wrapped up in rag: such of the needles as have their points towards the rag enter it, and can be drawn out and turned over without any difficulty; and in this way the 40,000 needles can be easily and quickly arranged in trays, with the points all in one direction. The eyes are now *drilled*, in order to get rid of the rough or jagged surface of the interior edges of the eye; but preparatory to this, the metal about the eye requires to be softened, which is done by placing a number of needles on a steel slab with their eyes projecting over the edge. A hot plate is then brought under the eyes, but so as not to touch them; when in less than a minute a film of a dark blue oxide covers the metal about the eyes, and indicates the proper temper for drilling. The drills are small three-sided tools, revolving horizontally with great speed, arranged at a well-lighted bench (fig. 465). A young woman with keen eye and steady hand, taking a few needles by the points, spreads them out like a fan, and brings the eye of each up to the drill; and by a motion of the finger and thumb presents



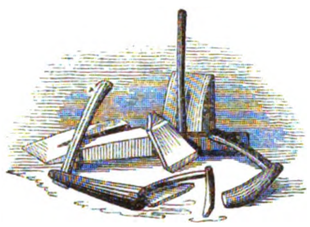
467. CUTTING FILES.



468. HARDENING FILES.

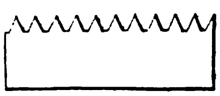


469. CUTTING THE TEETH.

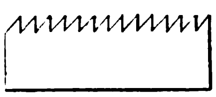


470. FILE CUTTER'S TOOLS.

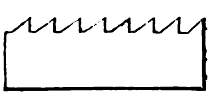
471. SETTING THE TEETH.



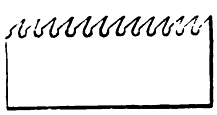
472. CROSS-CUTTING SAW.



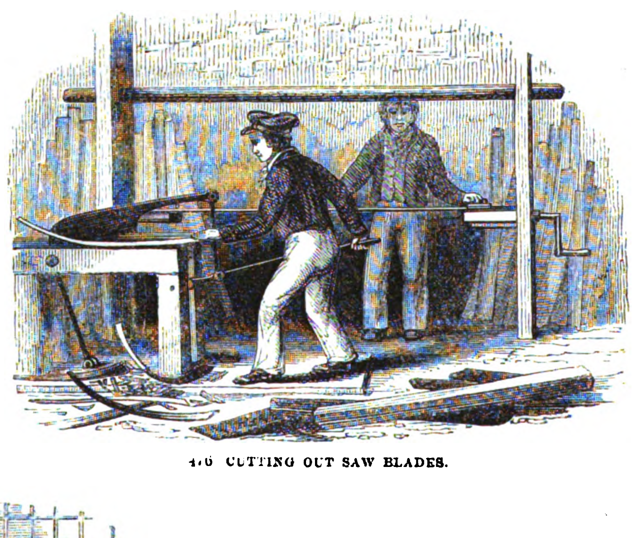
473. HAND-SAW.



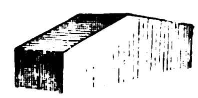
474 MILL-SAW.



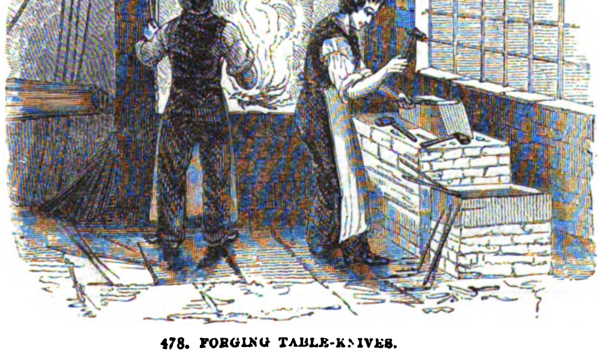
475. PIT-SAW.



476. CUTTING OUT SAW BLADES.

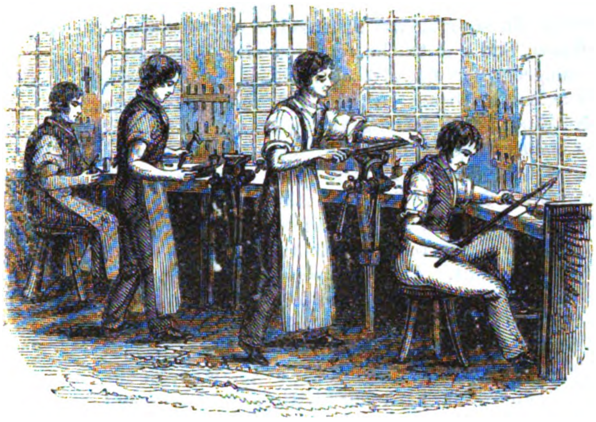


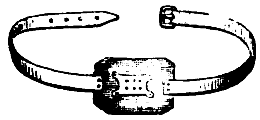
477. SAW-SETTER'S ANVIL.

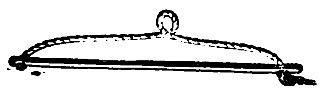


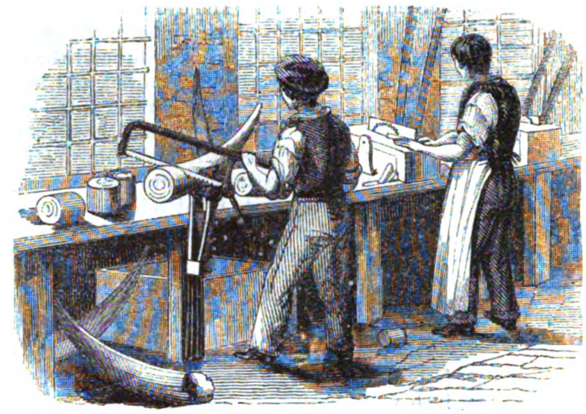
478. FORGING TABLE-KNIVES.

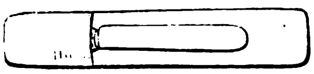
479 GRINDING CUTLERY.

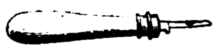

480. CUTLERY WORKSHOP.


482. BREASTPLATE.


483. BORING STICK.

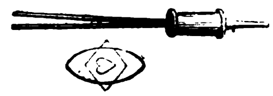

481. PREPARING IVORY HANDLES.

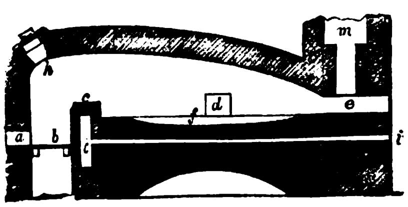

484. HOLDER.


485. HOLDER.

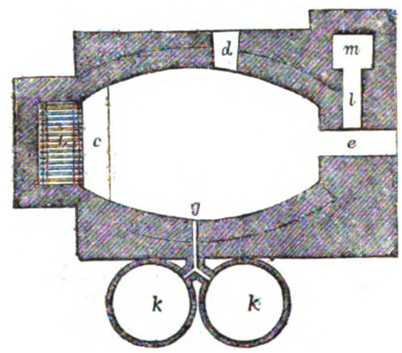

486. FORK MOOD.


487. DRILL.

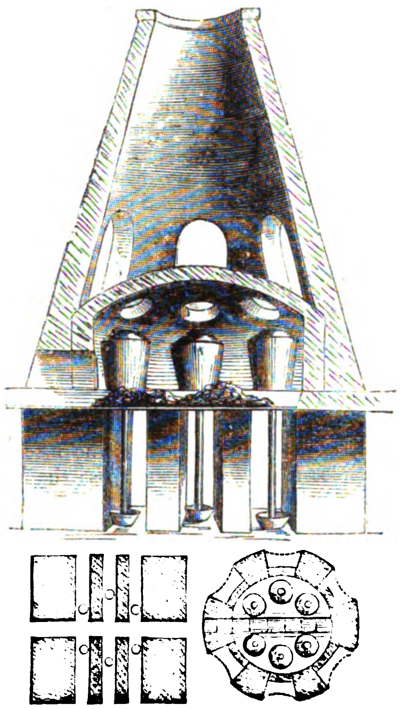

488. DOUBLE DRILL.



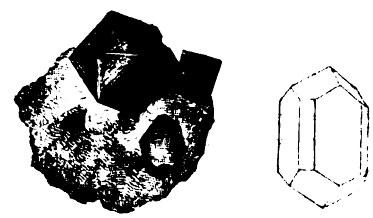
489. TIN SMELTING FURNACE.

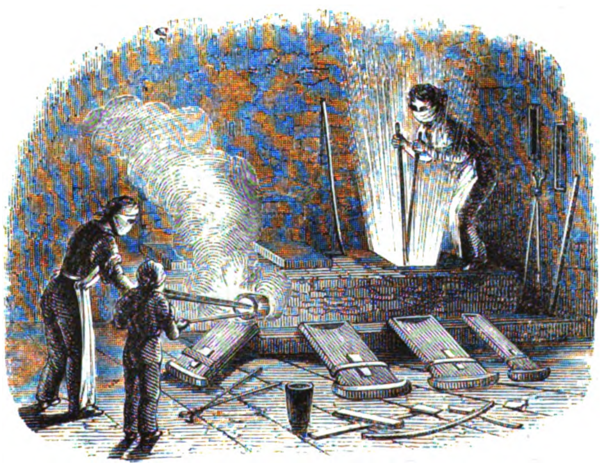


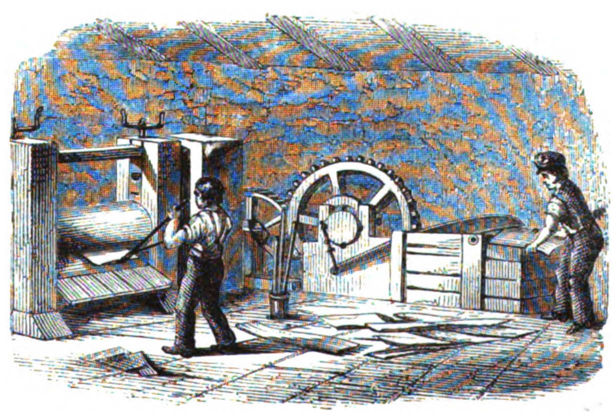
490. PLAN OF TIN SMELTING FURNACE.


491. ZINC FURNACE.


492. FILLING CRUCIBLES (*Brass*).


493. TIN CRYSTALS.


494. CASTING BRASS.


495. ROLLING COPPER.

either side at pleasure. The eye is first counter-sunk, by which means the sharp edge which connects the eye with the gutter is rounded. The drill is then passed round the rest of the edge of the eye, the ragged parts are removed, and that kind of form is given to the eye which may be noticed in the loops of a small pair of scissors. The points of the needles are next finished on a small stone, and then polished with polishing paste on buff wheels. Lastly, the needles are counted into quarter hundreds, folded up in blue papers, and labelled. If intended for exportation, the bundles are made up into square packets, and these are packed in cases of tinned iron. In the course of the manufacture the needles are repeatedly examined to see that the work is properly done, and to weed out defective specimens.

Files.—Files are almost as numerous as the work which they perform is varied. They may vary in length from three-quarters of an inch to two or three feet and upwards; and they are distinguished as *taper*, *blunt*, and *parallel;* the first kind being most numerous: those of the second kind terminate in a square or blunt end. Both these kinds swell out towards the middle, so that the sides are somewhat arched or convex; and even those files which are called parallel are a little fuller in the middle. Files are also known as *Sheffield-made* and *Lancashire-made;* the latter being produced at Warrington, and consisting mostly of the finer varieties, such as are used by watch and clock makers. Files may also differ in the forms and sizes of the teeth. In *double-cut* files, two series of straight chisel-cuts are made to cross each other, so as to raise on the surface of the file an immense number of points or teeth. In *single-cut* files a number of ridges are raised square across the file, by means of one series of straight chisel-cuts. Such files are called *floats*, the file properly so called being always double cut. A *rasp* is formed by dotting over the surface of the steel with separate teeth, by means of a pointed chisel or punch.

Files are made of steel; and the teeth are cut with a chisel, shown in fig. 470, which is struck with a peculiarly-shaped hammer, also represented; the file-cutters at work being shown in fig. 467. The blank is held on the anvil by a leather strap passing over each end of the blank and under the feet of the workman; and, to prevent injury to the metal, the blank is supported by a block of lead and tin. The blow of the hammer upon the chisel throws up a trifling ridge or bur; and after each blow the man immediately replaces the chisel on the blank, and slides it away from him until it encounters the ridge previously thrown up; this arrests the chisel, and guides the man in making his blow. In this way from sixty to eighty cuts may be made in a minute; the first course of cuts being somewhat deeper than the second. Round files are cut in a similar manner; rows of short cuts being made from the bottom to the top of the file; and these cuts, uniting at their extremities, form a series of complete lines round the cylinder.

The metal is in a soft state while the teeth are being cut. After the cutting, the files are hardened: they are first drawn through beer-grounds, yeast, or some other adhesive fluid, and then through a mixture of common salt and charred cow's hoof; the object being to protect the teeth from the action of the fire. The files are raised gradually to a dull red heat, and suddenly cooled by plunging them into a cistern of water (fig. 468). They are then scrubbed, dried, smeared with a mixture of olive oil and turpentine, and tested; when they are ready for market.

Saws.—Saws form a numerous class of tools. The size and form of teeth, the dimensions of the blade, and the method of mounting vary with the uses to which the saw is to be applied. In an ordinary *mill-saw* (fig. 474), the teeth are right-angle triangles; in the *pit-saw* (fig. 475), they consist of a succession of demi-lunettes, this being the keenest form for cutting. Fig. 472 is the *cross-cutting* saw, with spaces at the bottom to prevent the teeth from being choked up with sawdust. In the carpenter's *hand-saw* (fig. 473), as in most other common saws, the spaces at the bottom of the toothing are omitted.

The best material for saws is cast steel, rolled out into plates of uniform thickness, and cut to the required size by means of stout shears, arranged as in fig. 476. The edges of the pieces being ground true, the teeth are cut at a fly-press (fig. 469) by means of a steel die-cutter, working vertically in a steel die. When one tooth is cut, the man shifts the notch into an upright piece of steel, which fits it exactly, and then cuts out another notch, which in its turn is moved into a steel die, when a third notch is cut out; the metal between every two notches forming a single tooth, while the guide serves to keep all the teeth equidistant. After the teeth have been cut, the blade is put into a vice, and the wiry edges left by the punch are filed down, and the teeth finished. The blade is next hardened by being raised to a cherry-red heat, and plunged edgeways into a bath of cold oil, grease, pitch, &c., according to the fancy of the maker. The blade is now very hard and brittle, and is tempered by being stretched in an iron frame, and heated until the unctuous matter on the surface takes fire; the blade is then removed from the fire, and left to cool. *Back-saws*, or those which are afterwards furnished with a brass or iron back to keep them straight, are made in lengths of several feet, and are afterwards cut up. Small saws are not put into frames during the tempering, but are held in the furnace by means of tongs until the unctuous matter begins to "blaze off," as the workman calls it. *Planishing* or *smithing* is the next operation, in which the saw is placed on a small anvil of polished steel, and assiduously hammered, but with that care and judgment which experience gives, so as to make the metal of equal density and elasticity throughout. The blade is next ground on large wheels or grindstones; after which it is again planished, and is next held over a coke fire until a slight degree of oxidation, indicated by a faint straw colour, is produced. This restores the elasticity, which was injured by the grinding. The blade is next passed lightly over the grindstone to remove the marks of the hammer; it is then smoothed upon a hard, smooth stone, and is lastly polished on a wheel, covered with buff leather and smeared with a composition of emery and suet. The blade is again planished or *blocked*, after which it is cleaned off with emery, so as to produce an even white tint and a level appearance. The saw is not even yet finished; for the teeth require to be *set*, to prevent them from becoming choked up with saw-dust. This *setting* consists in bending every alternate tooth a little on one side, and the intermediate teeth a little on the other side. For this purpose the setter places the teeth on the ridge of a small anvil (fig. 477), and with a light hammer runs along the teeth, striking every other tooth so as to bend it a little; and then, turning the saw over, strikes the intermediate teeth. This delicate operation (fig. 471) is performed with great rapidity and precision; it seems scarcely possible that the intended effect should be produced without breaking off some of the teeth, or failing to hit the right tooth at the right moment. The saw is next placed in a vice, and the teeth are filed up; it is again held over the fire, and the film of oxide formed upon it is afterwards washed off with a weak acid: and at length the saw is ready for *handling*. Beech is the wood usually selected for handles.

Cutlery.—The various articles which are included under the term cutlery are or ought to be manufactured of steel. In some cases, however, the working parts of the tool or instrument are alone made of that metal. Cast steel can be readily welded to iron; so that the, cutting parts of chisels, plane-irons, &c. may be formed of it, and the rest of the tool of the inferior metal. Where not much hardness is required, as in table-knives, scythes, plane-irons, &c., shear-steel is used; but articles requiring a fine polish, such as razors, penknives, scissors, &c., ought to be made of cast steel.

In the production of a table-knife, the blade is first roughly forged from a bar of shear steel (fig. 478), and is then cut off and welded to the end of a rod of iron, about half an inch square, and a portion of this is cut off, sufficient to form the *bolster*, or shoulder, and the *tang*. The proper size and shape are given to

the bolster by introducing that part of the metal into a die on the anvil: a hollow mould or *swage* is then put on it, and a few smart blows are given to it with a hammer. The blade is next heated, and properly finished on the anvil: this is called *smithing* the blade: the maker's mark is stamped on it, and the blade is hardened by raising it to a red heat and plunging it into cold water: it is tempered to a blue colour, and is then sent to the grinder. The grinding and polishing of cutlery are carried on at Sheffield, which is the seat of the trade, mostly in buildings called *wheels* or mills; each mill being divided into a number of separate rooms called *hulls* (fig. 479). Most small articles are ground upon a dry stone; this produces those fatal consequences to the workmen, which were alluded to when describing the pointing of needles. The proper ventilation of the stones, however, has done much to remove or mitigate the evil: and the dust collected in a trough of water at the extremity of the ventilating shaft is large in quantity, and seems to have the density of metal. The fan which rarefies the air in the ventilating shaft is made to revolve by the same means which gives motion to the grindstones; so that the ventilating arrangements, not being subject to the will or caprice of the men, are likely to be efficient.

The proper shape is given to the blade by grinding; and as the concavity in such articles as razor-blades depends on the size of the stone, it is important to select the proper size. A stone four inches in diameter will give a corresponding concavity to the blade, or a curve of two inches' radius; and such a curve will evidently yield a keener edge than can be produced from a six, eight, or twelve-inch stone; because the smaller the diameter, the more convex is the stone, and the more concave will be the blade that is ground upon it. The friction of the blade against the stone produces great heat, so that some contrivance is necessary to protect the grinder's hands. Table-knives are fitted in a wooden case (fig. 484): penknives in a holder (fig. 485). After grinding, the blades are glazed on wheels of wood, or wooden wheels faced with leather, or with an alloy of lead and tin: they are then polished on buffs, dressed with crocus of iron.

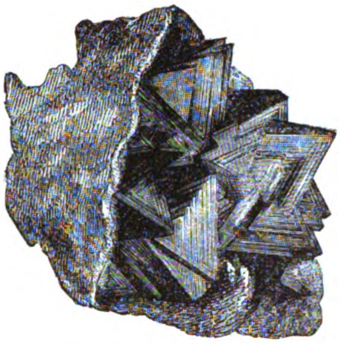
There is a large consumption of ivory for the handling of knives, forks, &c. The best method of attaching handles to knives and forks is to fasten a flat piece of ivory upon each side of a flat piece of iron continued from the blade: the next best method is to drill a hole through the length of the handle, to pass the prong of the knife through the hole, and rivet it at the opposite end: this is called *through-tang*. The most common method is to pass the prong about half-way into the handle, and to secure it with melted resin mixed with whitening. Such a handle, however, will become loose when the knife is put into hot water. *Balance-handles* are made by perforating the haft deeper than usual, and dropping in a small piece of lead; the knife then rests upon the handle and the shoulder, and the blade does not come in contact with the table-cloth. In preparing the handles, the tusks, whether of the elephant or of the walrus, are cut up first with a small frame saw, and then with a circular saw (fig. 481). Stag-horn handles are softened by boiling to bring them to the proper shape; cow-horn is brought to the proper shape by means of iron moulds, assisted by heat. Various other materials are used for handles, such as tortoise-shell, mother-of-pearl, fancy woods, stamped gold and silver, &c.

The processes of the cutler's workshop (fig. 480) are numerous and minute, even for a common article of cutlery. A common penknife with three blades has to pass through the workman's hands at least one hundred times. When the blades, spring, and *scales* (or thin metal supports to the handle) are bored with the proper holes, they are pinned together, to see that the parts fit and work well: they are then riveted with bits of wire, with a hammer on a small anvil. The horn, ivory, or shell sides are filed smooth, scraped, and polished twice on the buff; first with Trent sand, and then with oil and rotten-stone. The backs of the springs are glazed and then polished with a steel burnisher: holes are bored with a steel drill, passed through a wooden cylinder, fig. 487. Motion is given to this by means of a *boring-stick*, fig. 483, the thong of which is twisted round the cylinder of the drill; the short end of which is held against a breast-plate, fig. 482, which is strapped round the workman's body. A *double-drill*, fig. 488, is used for hollowing out the cavity for the shield or plate of silver let into one side of the handle. This drill consists of two elastic steel blades, sharp at one end. A plate of steel, perforated according to the required shape of the shield, is placed on the handle, and within this perforation the two ends of the drill are held, and made to revolve by means of the boring-stick. The tendency of the springs to coil round each other by the motion, and to fly asunder by their elasticity, causes them to describe a number of small circular arcs; and as the man constantly moves the points over every part of the circumscribed space, the cavity is soon hollowed out: the plate or shield is then driven in, and is held in its place by two pins projecting from the under-surface.

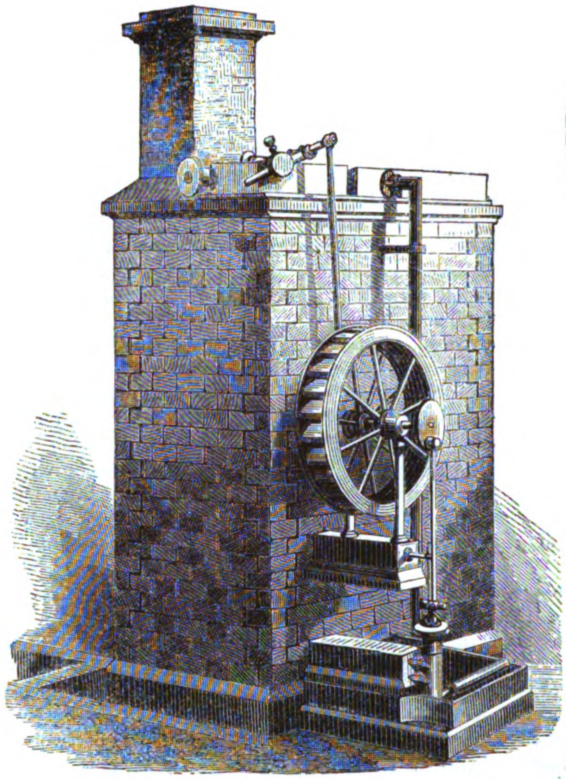
A good idea of the extent of our manufactures in iron and steel may be formed from the value of our exports in 1859. Under the head of machinery we exported steam-engines to the value of 978,445*l*., other sorts of machinery to the value of 2,722,649*l*.; pig-iron to the value of 894,917*l*.; bar, bolt, and rod-iron, 2,372,488*l*.; railway-iron, 4,143,066*l*.; iron-wire, 228,023*l*.; cast-iron, 796,325*l*.; wrought-iron of all kinds, except railway-iron, 3,085,933*l*.; unwrought steel, 691,627*l*.; hardwares and cutlery, 3,826,030*l*.

XXVII.—TIN, ZINC, BRASS, AND COPPER.

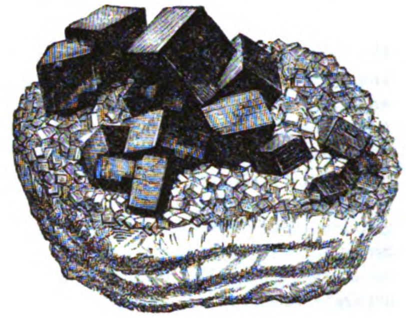
We have already described the mechanical operations by which the ores of tin are separated from their stony matrix, and prepared for the smelter. The furnace in which the prepared ores are reduced is represented in vertical section fig. 489, and in plan fig. 490. *a* is the *fire-door*, through which the fuel is placed upon the grate *b*; *c* is called a *fire-bridge*; at *d* is a door for the introduction of the ore; and at *e* is another door, through which the ore is worked upon the hearth *f*; *g* is the *stoke-hole*; *h* is a hole which is occasionally opened to admit a draught of air for carrying the fumes up the chimney, *m*; *l* is a flue; at *i i* are channels for admitting cold air under the fire-bridge and hearth, to protect them from the heat; *k k* are basins into which the melted metal is drawn off. The ore is mixed with small coal, and a flux of slaked lime; and it is damped with water to prevent the draught from sweeping away the finer portions. When the furnace is charged, the doors are closed and *luted*, or stopped with clay, and the heat is gradually raised. In the course of six or eight hours, the reduction of the oxide is completed; the door of the furnace is removed, and the melted mass is worked up to complete the separation of the scoriæ. About three-fourths of the scoriæ are rejected as refuse; a second portion contains about five per cent. of tin, and is sent to the stamping mill; while that last removed contains much tin, and is set aside for smelting over again. The channel leading to the basins *k k* is then opened, and from the basins the tin is lifted in iron ladles, and poured into iron moulds. These blocks



496. BLENDE, OR BLACK JACK.



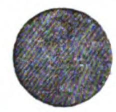
498. FUME CONDENSER



497. GALENA.

500. SHELL.

501. COLLET.

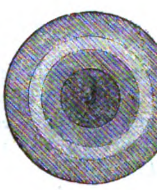


502. COVERING.

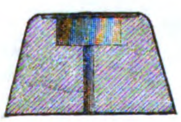
503. SHANK.

499. STAMPING FORKS.

506. HOLLOW TOOL AND MOULD.

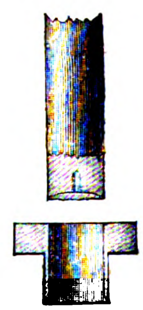


504. PADDING.

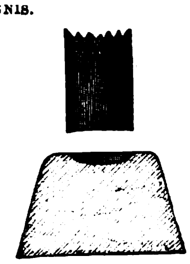


505. MOULD.

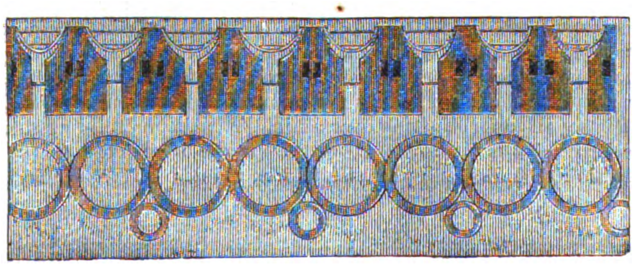
509. HARDWARE FROM TUNIS.



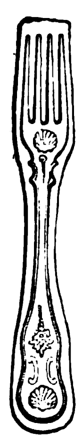
507. HOLLOW TOOL.



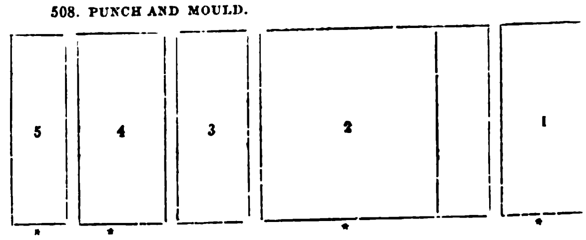
508. PUNCH AND MOULD.



510. MELTING-POTS.



511. STAMPED FORK.

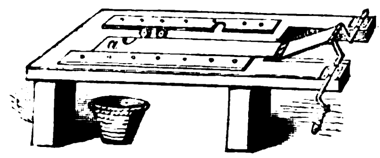


512. ARRANGEMENT OF POTS FOR TINNING.

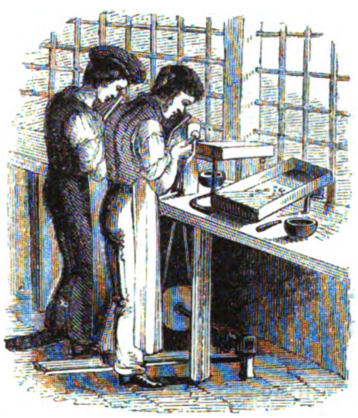
514. CLEANING.

513. CUTTING OUT BLANKS

516. SHANKING.



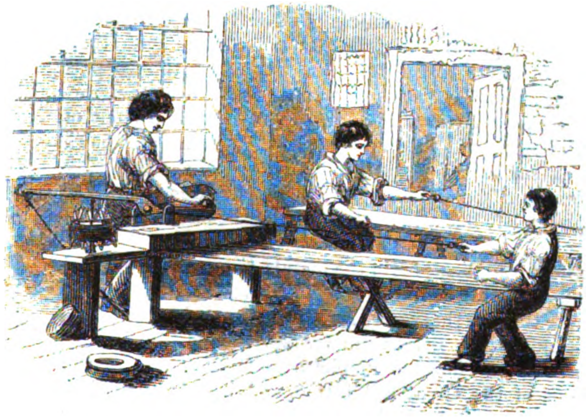
515. ROUNDING THE EDGES



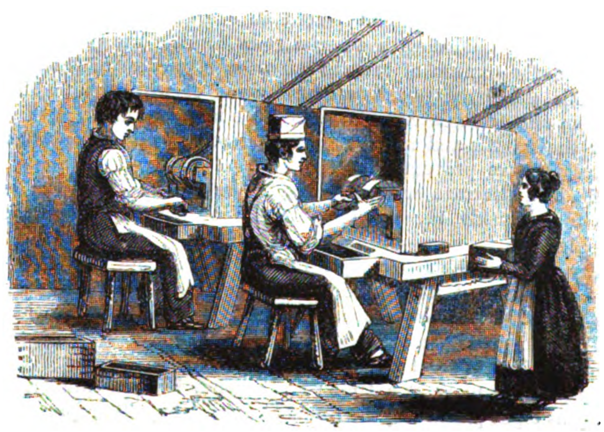
518. BURNISHING.

517 DRYING OFF.

520. FIXING THE HEADS.



519. STRAIGHTENING THE WIRF.



521. POINTING

of tin are further purified by *refining*, which is done by arranging the blocks in a furnace near the bridge, and raising them to a moderate heat: the tin melts, and flows away into the refining basin, leaving most of the impurities behind. Other blocks of tin are arranged on the remains of the first; and when about five tons of melted metal have been collected, billets of green wood are plunged into it, the effect of which is to give the tin the appearance of boiling: a kind of froth rises to the surface, but the most impure and heaviest portions fall to the bottom. The froth is skimmed off, and the tin is left to settle: it separates into different portions, of which the top stratum is the most pure, the bottom the most impure, and the middle of average purity. The tin is ladled into iron moulds, forming blocks of about three cwt. each, known as *block tin*. The tin of the first stratum is called *refined tin*, and is chiefly used in the manufacture of tin plate.

Zinc being volatile at a high temperature, its ores are distilled in crucibles or pots, six or eight in number, contained in a cupola furnace, fig. 491, arranged somewhat like the pots of a glass furnace, fig. 276. In the bottom of each pot is a hole which is closed with a wooden plug. The charge for each pot, consisting of six parts calamine and one part coal, is put in from above, through an orifice in the lid of the pot, which is left open after the firing, until the bluish colour of the flame shows that distillation has begun. The hole is then covered with a fire-tile. The sole of the hearth on which each pot stands is perforated below: when the fire has heated the pots and consumed the wooden plugs, the end of a long sheet-iron pipe is put into each hole; the other end dipping into a vessel of water, which receives the condensed vapours of the zinc in drops and in a fine powder, mixed with a little oxide: this distilled zinc is melted in an iron vessel, and is cast into square bars or ingots.

The smelting of copper involves a long and complicated series of operations, which cannot be described here. The union of copper with zinc forms a number of useful alloys, depending on the proportions of the respective metals. Copper with about half its weight of zinc forms yellow brass. One pound of copper, with from one to one and a quarter ounces of zinc, forms *gilding-metal* for common jewellery. When the proportion of zinc is increased to three or four ounces, we get *Bath metal*, *Pinchbeck*, *Mannheim gold*, *Similor*, &c. With sixteen and a half ounces of zinc, we have *Mosaic gold*.

The furnace in which the copper and zinc are melted is a small wind-furnace, with the mouth standing eight or ten inches above the floor of the foundry. The crucibles are filled with the proper proportions of the two metals, well rammed in (fig. 492), and when, by proper attention to the temperature, which is maintained by means of coke, the alloy is supposed to be formed, the covering of the furnace is thrown off, and a man, striding over the opening, grasps the crucible between the jaws of a pair of tongs, and lifts it out of the furnace (fig. 494). After skimming, the crucible is seized with a pair of tongs, and the contents poured into an iron mould placed in a sloping direction, the stream being guided with an iron rod. During the process of pouring, the oxygen of the air seizes on a portion of the zinc and fills the foundry with a dense cloud of white oxide. To prevent this from entering the lungs, the men tie a handkerchief over the mouth and nostrils. The effect of this white cloud seems to have prevented our artist from seeing clearly; since in fig. 494, the man who is filling the mould appears to have the tongs inside the crucible, instead of grasping it on the outside.

The cast plates are usually rolled into sheets, for which purpose they are cut into ribbons, which are passed cold through the rollers. The metal soon becomes too hard for lamination, and has to be softened in an annealing furnace. The ragged edges are cut off, and the sheets are then passed through the rollers two or more at a time; and as they become thinner, as many as eight plates may be rolled at once. Fig. 495 represents the rolling of copper.

Most of the lead of commerce is obtained from galena, or the native sulphuret (fig. 497). It occurs in veins in the primitive rocks, and is mixed with quartz, blende, pyrites, &c. Galena always contains a small portion of silver; sometimes as much as 120 ounces to the ton. The lead ore is separated to a great extent from earthy impurities by dressing, when it is mixed with lime, and heated to dull redness in a reverberatory furnace, through which a strong current of air is passing. A good deal of the sulphur burns off as sulphurous acid, and a portion of oxide of lead is formed: another portion of the sulphuret is converted into sulphate of lead. When the roasting, with much stirring, has been carried far enough, the furnace-doors are closed and the heat is raised. The oxide and the sulphate of lead react upon the undecomposed ore; a good deal of sulphurous acid escapes, and metallic lead runs freely from the mass into cast-iron basins. The lead may be refined or *improved*, as it is called, by passing it through the furnace again. The escape of sulphurous acid, together with a portion of lead in the form of *fume*, causes much loss to the smelter and annoyance to the neighbourhood; destroying vegetation and poisoning the cattle. Many attempts have been made to condense this fume, the most successful of which is the apparatus used at the Duke of Buccleuch's works at the Wanlock-Lead Hills in Dumfriesshire. A portion of this apparatus is represented at fig. 498. It is divided within by a partition wall into two chambers; and the smoke from the various furnaces is brought by a suitable apparatus into these chambers, where it meets with descending showers of water, which condense it. We cannot explain this apparatus more distinctly without the use of sectional drawings; but we may state its success in the fact that, before it was erected, the heather was burnt up, vegetation destroyed, animals could not graze, nor birds feed near the spot; but that after its erection, the heather was seen in luxuriance close around the works; sheep were grazing within a stone's throw of the base of the chimney, and game was sheltering on all sides.

The best method of separating silver from lead depends on the fact, that if the melted lead be allowed to cool slowly, and be stirred during the process, a portion of the metal solidifies in the form of crystalline grains, which sink to the bottom: these grains consist of lead nearly free from silver, since the fusing point of the argentiferous alloy is lower than that of pure lead. In separating the silver, a number of cast-iron pots (fig. 510) are set in brickwork in a row, with a separate fire beneath each; about five tons of lead are melted in the middle pot, when the fire is withdrawn and the metal is briskly stirred: as the crystals of lead subside, they are removed by means of a perforated iron ladle to the next pot on the right hand. When about four-fifths of the lead is thus removed, the concentrated argentiferous alloy is ladled into the next pot on the left, and the empty pot receives a fresh charge. The straining off of the lead is thus continued from pot to pot, the argentiferous portion being continually passed on to the left, and the poorer portion to the right. The last pot on the left may thus become filled with lead, which may contain three ounces of silver to the ton; while the lead in the last pot on the right does not contain more than half an ounce of silver to the ton; the latter is cast into pigs for the market; but the former is passed through a *cupel* furnace, and being exposed at a high temperature to a current of air, the lead is converted into an oxide, which melts and flows off the convex surface of the melted metal; thus continually exposing a fresh surface of lead to the action of the air, until at length nothing is left but a cake of pure metallic silver.

Hardware.—The applications of the metals, tin, copper, lead, and zinc, and their alloys, are so numerous that it would be impossible even to indicate them in this place. An immense number of articles are included under the general term *hardware*, the most primitive forms of which were collected in picturesque confusion in the Tunisian Court of the Great Exhibition, and are represented in a striking engraving, fig. 509. Birmingham is the centre of the

hardware trade of this country; and in its practice, we frequently notice the useful arts merging into the fine arts through the medium of the ornamental. From cabinet and general brass foundry, such as hinges, fastenings, bell-pulls, &c., we arrive at works in stamped brass, such as cornices, curtain-bands, finger-plates, where a certain amount of taste in design is required, until we come to gas-fittings, chandeliers, lamps, and candelabra, where taste admits of a higher development; and lastly, we have bronze figures, busts, and chimney ornaments, in which the taste, if not the genius, of the finished artist ought to prevail.

In copper, zinc, tin, pewter, &c. we have such common articles as kettles, coal-scuttles, saucepans, which are not remarkable for taste; and bronzed tea and coffee urns, &c., which, taking their place on a drawing-room table, ought at least to gratify the eye by their beauty of form. The same remark applies to teapots and articles in German silver. The term *hardware* also includes a number of objects, made of mixed materials, such as metallic buttons, Florentine, mother-of-pearl, bone buttons, &c. The metal zinc is commonly used for objects which, until recently, have been represented in tinned sheet iron. Articles in iron and steel are innumerable, including as they do stoves, grates, fenders and fire-irons, locks, hinges, and general ironmongery; hollow-ware, cast and wrought, tinned and enamelled; garden and other tools, nails, and screws, steel toys and ornaments, steel pens, needles, fish-hooks, &c. &c.; but as the modes of production of articles in iron and steel have already engaged our attention, we may pass over these with one exception; and that is, the application of tin to the covering of sheet iron in the production of what is called tin-plate.

Tin-plate.—The best sheet iron is used for this purpose; and the first step towards tinning is to clean the plates, for which purpose they are bent in the middle, and placed on edge in a trough containing a solution of hydrochloric acid. They are then conveyed to a furnace, heated to redness, and after cooling are straightened by being beaten on a cast-iron block. This gets rid of oxide: the plates are further smoothed by being passed between rollers, and are put one at a time into an acid mixture of bran and water. They are next pickled in a solution of sulphuric acid, assisted by a gentle heat, washed in cold water, and scoured with hemp and sand. The surfaces are now chemically clean, for without such precautions the tin would not adhere. The tin is melted in a cast-iron vessel, and is protected from the oxidizing influence of the air by a covering of tallow. By the side of the tin pot is a pot filled with grease only, for receiving the prepared plates, previous to tinning: they are taken out of this one by one, and plunged into the tin in a vertical position, to the number of 200 or 300, where they are left for an hour. After this they are taken out with tongs, and placed on an iron rack or grating, where a good deal of tin drains away from them; but a larger quantity is got rid of by the process of *washing*. An iron pot, called the *wash-pot*, is filled with melted tin, and by the side of it a *grease-pot* full of clean melted tallow. There is also a third pot called the *pan*, with a grating at the bottom for receiving the plates when taken out of the grease-pot. A fourth, called the *list-pot*, contains only a small quantity of melted tin. Fig. 512 shows the arrangement of all the pots. No. 1 is the tin-pot, in which the plates are first tinned. No. 2, the wash-pot, divided into two portions to facilitate the separation of the dross. No. 3 is the grease-pot. No. 4, the pan; and No. 5, the list-pot. The stars show where the work-people stand. In the operation of washing, the wash-man puts the plates already tinned into the wash-pot, and the heat of the tin contained in it soon melts all the loose tin on the surface of the plates: the wash-man inserts a pair of tongs into the tin, catches up a plate, brushes it on both sides with a hempen brush, dips it for a moment into the hot tin, and plunges it into the grease-pot, No. 3. The grease-pot has pins fixed within it to keep the plates asunder; and when five plates have been transferred to it, a boy removes the first into the cold-pan, No. 4; and as soon as the wash-man has transferred a sixth plate, the boy removes a second, and so on.

The plates are left in No. 4 until they are cold enough to be handled. As the plates are placed vertically in the melted tin and in the grease-pot, there is a *list* or selvage of tin on the lower edge of each plate, which is removed by dipping such edge into the list-pot, No. 5, which contains melted tin to the depth of about a quarter of an inch. When the list is melted, the boy takes out the plate and gives it a smart blow with a thin stick, which removes the superfluous metal. The plates are cleansed from grease by rubbing them with warm dry bran: they are lastly packed in boxes, each containing a certain number of plates, according to their quality, which is distinguished by certain marks attached to the boxes.

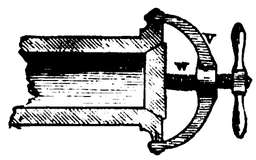
Stamping.—A number of small articles are produced by *stamping*. Thus, the prongs of forks are sometimes formed in this way. The fork is first forged from a rod of steel; the tang, the shoulder, and the shank are roughly made out and cut off, leaving at one end about an inch of the square part of the steel rod, which is drawn out flat to about the length of the prong. This produces a *mood* or mould (fig. 486), which being softened by heat is placed in a steel boss or die, upon which a second boss, connected with a heavy block of metal, is made to fall from the height of several feet; this forms the prongs and central part or *bosom* of the fork, leaving between the prongs only a thin film of steel, which can be cleaned out with a file. Many plated goods are formed in this way, such as the stamped fork, fig. 511. The stamp is fastened to one end of a rope, which is passed over a pulley at the top of a frame, fig. 499; while to the other end of the rope is a stirrup, in which the workman places his foot, raises the stamp to the required height, and allows it to fall suddenly upon the metal contained in the lower die. A rim of thin metal is left between the prongs and around the fork, which can be easily cleared away.

Buttons.—During many years, when it was the fashion to wear gilt buttons, the button manufacture held the foremost rank among the Birmingham "toy trades," as Hutton styles the traffic in these and similar articles. Probably no article in extensive demand is more subject to the caprices of fashion than buttons: they not only undergo frequent changes in size and form, but also in material. All the kingdoms of nature are ransacked to gratify the love of novelty: thus we have buttons of metal, of horn, of shell, of ivory, of bone, of glass, of mother-of-pearl, of jet, of precious stones, of embroidery, and of silks and stuffs of all kinds. Most of these materials must be regarded as modern innovators. The gilt button long continued to reign supreme; and was even protected by Acts of Parliament, which regulated the make, and attached penalties to any person who should presume to cover button moulds with the same kind of cloth as the coat. At the time when this absurd law was passed, silk was too costly a material for covering buttons, and other forms of covered buttons had not been invented; so that gentlemen were compelled to use the much-favoured gilt button on coats and vests. There is still a demand for the gilt button, and we cannot do better than describe its manufacture.

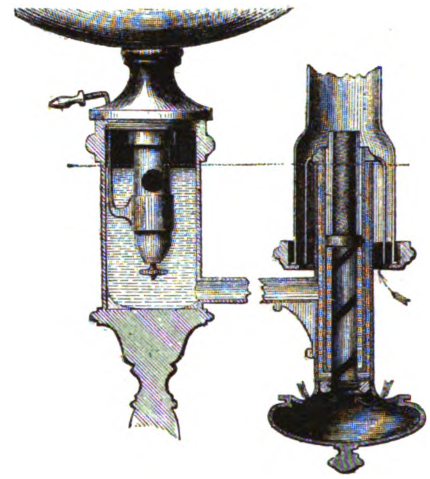
The gilt button is made of sheet copper, with a small alloy of zinc. Strips of this, of the proper thickness, are furnished to the button-maker; and from these *blanks* or circular pieces are cut out by means of the presses shown in fig. 513. The sharp edges of the blanks are smoothed and rounded by rolling them between two parallel pieces of steel, fig. 515; the piece *a* being movable, and the opposite piece fixed. The blanks are next smoothed on the face by means of a steel hammer, and are then ready for the shanks; these are formed by machinery, and are applied by hand (fig. 516): the shank, being placed in position, is held there by a small spring clasp; and a little solder and resin being heaped round the shank, the heat of an oven melts the solder and secures the shank. Hundreds of blanks are arranged on an iron plate and placed in the oven at the same time. If the button is to be ornamented with a crest or other device it is

522. CANDLE.

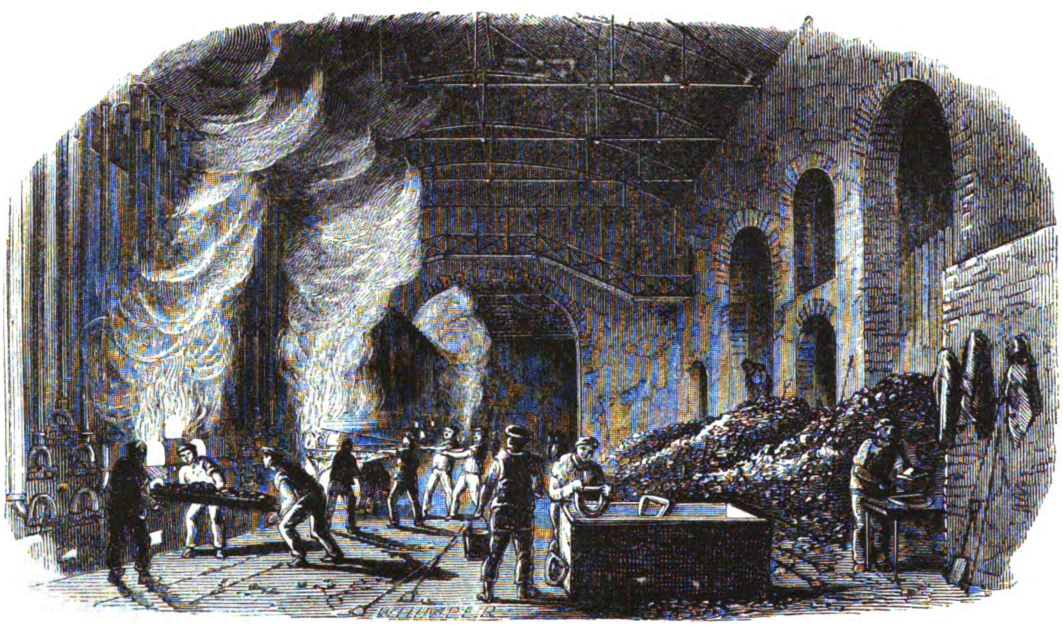
524. RETORTS.



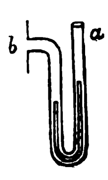
525. MOUTH OF RETORT



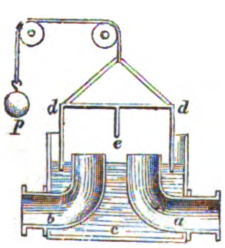
523. ARGAND LAMP.



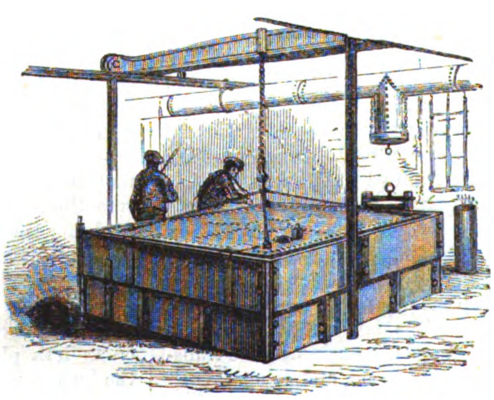
526. THE RETORT HOUSE, AT THE WESTMINSTER GAS-WORKS.



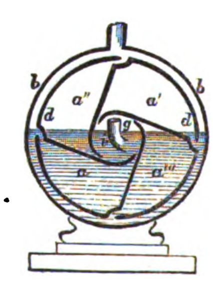
527. GAUGE.



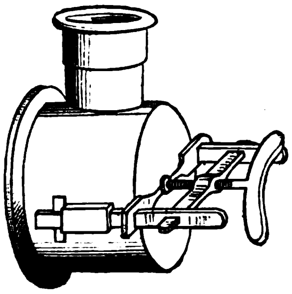
528. WATER VALVE.



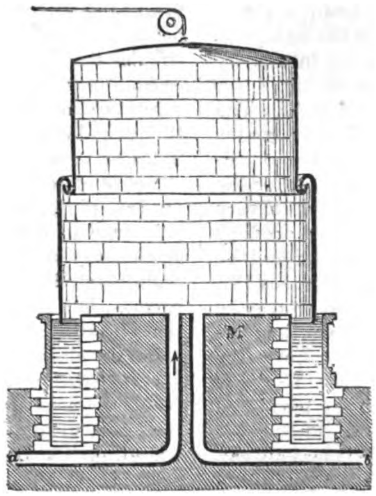
529. LIME PURIFIERS.



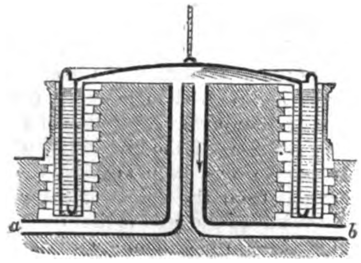
530. METER.



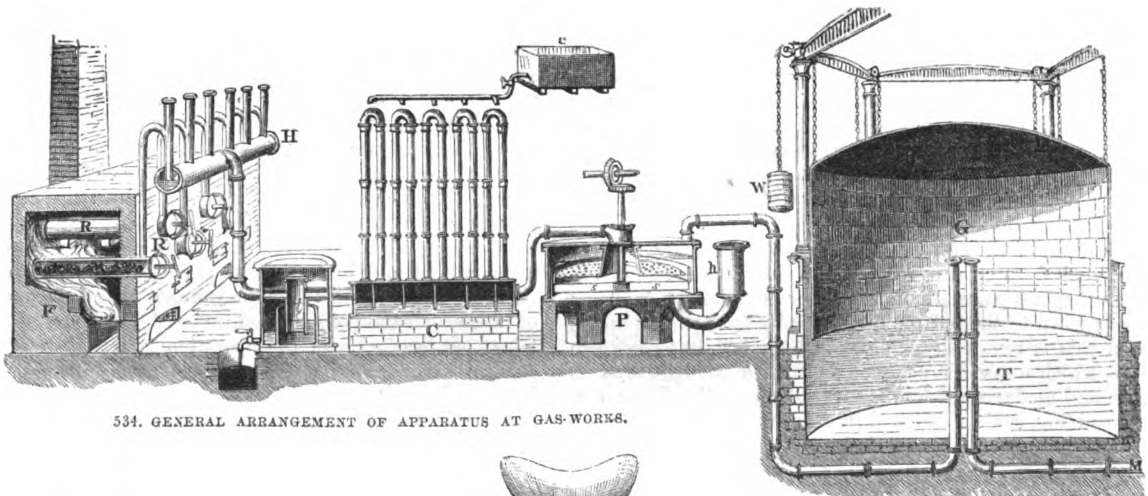
531. MOUTH OF RETORT



532. TELESCOPIC GASOMETER (*Open*).

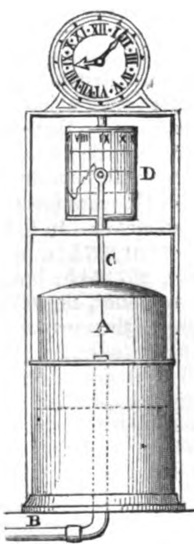


533. TELESCOPIC GASOMETER (*Closed*).



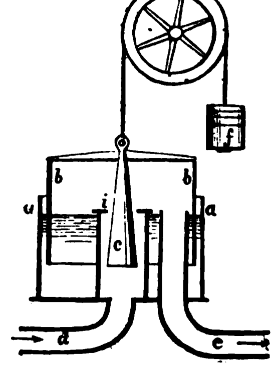
534. GENERAL ARRANGEMENT OF APPARATUS AT GAS-WORKS.

535. BAT'S-WING.



536. PRESSURE INDICATOR.

537. GASOMETERS.



538. THE GOVERNOR.

passed through a stamping-press (fig. 499); the lower die containing a hole for the reception of the shank during the stamping. The buttons are next cleansed by being stirred up in a weak solution of nitric acid (fig. 514); and are then thrown into a pan containing a solution of nitrate of mercury, or *quick-water*. The gold is dissolved in mercury, from two and a half to five grains being allowed for the gilding of 144 one-inch buttons, an astonishing instance of the divisibility of the precious metal. After the amalgam has been applied, the buttons are of a dull silvery colour from the excess of mercury, which must be removed by heat before the gold makes its appearance. For this purpose the buttons are placed in a wire cage, and the cage in a furnace (fig. 517); the buttons are kept in constant motion by turning the handle of the cage; and under the influence of the heat the mercury escapes in vapour, leaving the gold equally diffused over the surface of the buttons. They come out of the furnace of a dingy gold colour, and receive their beautiful lustre by being burnished with blood-stone in a lathe (fig. 518).

A covered or Florentine button, however simple it may appear, is really more complicated in its manufacture than the gilt button just described. The various parts of the button are cut out by fly-presses (fig. 513); and those parts consist,—*firstly*, of a metal *shell* (shown in front and sideways, fig. 500); *secondly*, a metal collet, fig. 501, containing an oblong hole for the shank of the button; *thirdly*, a circular piece of silk or other woven covering for the button, fig. 502; *fourthly*, the padding which lies under the collet, round which is wound, at right angles to the length of the oblong hole of the collet, a thread (as shown in fig. 503), which acts as a flexible shank to the button. The padding consists of several layers of paper, and a piece of silk or other fabric similar to the covering for forming the back surface. The various disks, consisting of the silk covering, a disk of paper to prevent the metal shell from cutting the silk, and the shell, are shown in fig. 504, as they are placed upon the die or mould, fig. 505. They are pressed down to the bottom of the die by means of a punch; and when this is removed, a hollow tool, fig. 506, is forced into the die, by which means the edges of the silk are brought towards the centre and made to overlap the edges of the shell. The collet, with the padding, is then dropped into the mould through a hollow tool, fig. 507; when a punch is brought down so as to force the padding and the edges of the outer covering into the shell. The button is then removed from the mould, fig. 505, by passing a wire up through a channel made for the purpose; and the final pressure is given to the button by means of a punch, fig. 508, for which purpose the button is put into the mould with the collet downwards and pressed into the die by the flat face of the punch.

Pins.—The manufacture of a pin is as remarkable in its way as that of a needle, and furnishes another instance of the value of subdivision of labour. Where a number of operations are required in the production of one article, it is desirable to keep one person or set of persons to one operation, so that by constant practice he may attain skill and rapidity in his particular department.

The pin-maker receives wire from the wire-drawer in a soft state, usually larger than he requires it. It is first cleansed by means of dilute sulphuric acid, and reduced to the required gauge or size by passing it through a draw-plate. It is straightened by pulling it through another draw-plate from the barrel on which it is wound, and running it out upon a low wooden bench to the length of twenty feet (fig. 519). That piece is then cut off, and another portion is similarly drawn out. These lengths are then cut up by shears into shorter lengths, each of which is capable of furnishing rather more than six pins. These lengths are next pointed at both ends at a machine called a *mill*, consisting of a circular single-cut file and a fine grit stone (fig. 521). As many as from fifty to eighty of the pin wires are held at the same time, a rotatory motion being given to them by the motion of the thumb and fingers. The fine brass dust thus produced is very injurious to health, unless the mill is properly ventilated. From the ends of each wire thus pointed, lengths are cut off, sufficient for two pins, and the intermediate portions returned to the pointer, who points the extremities as before; two lengths are again cut off from each wire, and the intermediate portions being again pointed furnish each two pins. The wire for the pin-heads is coiled in a compact spiral round a wire of the size of the pins; the central wire is then withdrawn, and two or three turns of the spiral are cut off for each head. The heads are put on by a girl, who is seated with a number of heads in her apron; and taking up a number of headless pins between her fingers, moves them through the heads with a threading kind of motion. The wires catch up a head, or it may be two or three heads each; the superfluous heads are stripped off, and the pins are placed one at a time in a mould, beneath a hammer which can be raised by the foot (fig. 520). The pin being in its place, point downwards, the hammer is allowed to descend; and, striking the top of the pin, moulds and fastens the head, and leaves the top smooth and round. The man instantly raises the hammer again; when a little spring under the die raises the pin so that it can be at once removed, and another made to take its place. In this way a man will head 1,500 pins per hour. In this state the pins are dingy and dirty; they are cleansed by being boiled in sour beer or a solution of tartar. Then comes the *whitening* or tinning: for which purpose about six pounds of pins are put into a copper pan, then seven or eight pounds of grain tin, then more pins, and more tin, until the pan is filled. Water is next poured in, and the pan is set on the fire; and when it is hot, the surface is sprinkled with cream of tartar, and the boiling is continued for an hour. The pins are taken out, washed, and the operation is repeated, if necessary. After the tinning, the pins are polished by being shaken in a leathern bag with bran. The bran is separated by winnowing, and the pins are collected in bowls for papering. The papers are crimped by means of crimping-irons; and the folds for one row being gathered together are placed between the jaws of an iron vice, which close by means of a spring. There are grooves across the jaws of the vice, to guide the paperer, who sits with her lap full of pins. Instead of taking them up one or two at a time, she passes a pocket-comb through the pins and takes up the number required for one row; and directing the points along the grooves, pushes the pins into the paper with great rapidity, by means of a metal guard on the left hand. She then pulls open the vice, gathers together the next row of folds, places them in the vice, and fills them as before.

Most of the processes above described can be imitated by machinery, in which case the head is formed by hammering out, or *upsetting*, the end of the wire between dies; but the chief objection to solid-headed pins is, that a soft wire is necessary, so that machine-made pins are more liable to bend than those made by hand.

We have given in a former page an account of our exports in iron and steel as an illustration of the extent of the manufacture. We may here do the same for the other common metals. In 1859, unwrought copper was exported to the value of 691,627*l.*; copper sheets and nails, 1,502,272*l.*; wrought copper, 257,351*l.*; brass, 149,057*l.*; lead in pigs, rolled and sheet lead, and shot, 480,943*l.*; lead ore, red and white lead, and litharge, 187,094*l.*; tin unwrought, 361,214*l.*; tin plates, 1,523,166*l.*

XXVIII.—ARTIFICIAL ILLUMINATION—GAS.

THE useful arts have been popularly arranged under the three great heads of FOOD, SHELTER, and CLOTHING. Without pausing to inquire into the accuracy of such a classification, we must admit that it includes a vast number of processes on which our physical comforts depend. Each of these terms, however wide its meaning, has different meanings among different people, and in different states of civilization. As man advances in wealth and intelligence, his food becomes more delicate, his dwelling more luxurious, and his clothing more refined; and the delicacy, the luxuriousness, and the refinement will vary with the climate, and with the natural productions of that part of the world which he inhabits. They will even vary according as he occupies an island or a continent, dwells near the sea or a great river, and is dependent for the supply of foreign produce on land or water carriage. Still, whatever be his condition and wherever he may dwell, he can scarcely fail to be benefited by the discoveries of science, and the improvements in the useful arts consequent thereon. The African chief who employs his people in collecting and shipping off to this country the palm oil which we now so extensively employ, receives our manufactures in return; and it was not very long ago that an iron house of two or three stories, with its furniture complete, was sent out as a residence for one of these dusky chiefs. Discoveries in chemistry, and the abundant supply of this palm oil, have enabled us greatly to improve our means of artificial illumination, just as the introduction of gas, early in the present century, improved our shops and streets, by making those more attractive and these more secure. Such improvements as these are among the landmarks of civilization. Inhabiting, as we do, a rigorous and uncertain climate, we create within our dwellings an artificial climate, suited to our wants, and artificial light, adapted to our occupations; thus bringing, as it were, the amenities of the south into the winter of the north. Nor do the advantages of these comforts end with the comforts themselves; the energy and enterprise required to secure them react favourably upon ourselves, and tend, among many other causes, to produce a race far superior to the inhabitants of the land where each man is said to have done his duty to society if, once in the course of his life, he plant a single bread-fruit tree; since nature will accomplish the rest, in supplying him and his family with food, shelter, and clothing.

There are few contrivances in the useful arts more beautiful than a candle. This is an ingenious contrivance for constantly supplying a flame with as much melted fat or other proper material as can be consumed without smoking. To this end the size of the wick must be nicely adjusted to the thickness of the tallow: if the wick be too large, there will be too much heat, too much melting of the tallow, and the candle will gutter; if the wick be too small, there will not be enough heat, and the tallow will form into a ring-shaped wall about the flame, as is the case in night-lights. But when the wick is of the proper size, the tallow immediately below the flame is melted into the form of a hollow cup (fig. 522), which forms a reservoir, always properly filled, for feeding the flame. The fibres of the twisted cotton of the wick act as a number of capillary tubes, and carry the liquid fat up into the flame; where, being exposed to a high temperature, and sheltered from the air, it undergoes a dry distillation: it is decomposed into an inflammable vapour, which rises by its lightness, and undergoing combustion as it rises, rapidly diminishes in quantity until it disappears in a point.

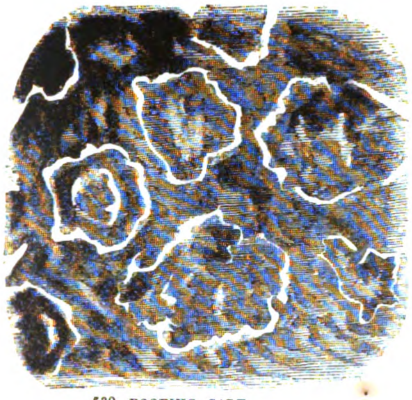
The flames used for artificial illumination, whether obtained from candles, lamps, or street gas, are produced by the combustion of compounds of hydrogen and carbon. These hydrocarbons, as they are called, consist of hydrogen gas holding carbon or charcoal in solution. The hydrogen supplies the flame, and the carbon the brilliancy: the flame of pure hydrogen has little or no illuminating power; but if we project through it a quantity of iron filings, or of charcoal powder, the flame immediately becomes brilliant. That all common flames contain charcoal in a state of minute division is evident from the fact that, if we introduce a cold body into a flame, the charcoal condenses upon it; or if we hold the flame of a candle near the ceiling of a room, it leaves a black mark from the precipitation of the carbon on the cold surface.

As soon, then, as the tallow is drawn up into the flame, it is resolved into a gaseous hydro-carbon; but combustion only takes place at the exterior of the flame, where it is in contact with the oxygen of the atmosphere. Here the oxygen unites with the hydrogen of the flame, and forms vapour of water; and here, too, the particles of carbon, coming to the surface, are seized on by the oxygen, undergo combustion at a white heat, and pass off in the form of invisible carbonic acid gas. No combustion is going on within the flame, but only distillation and decomposition, so that flame has been appropriately termed a luminous bubble of gaseous matter.

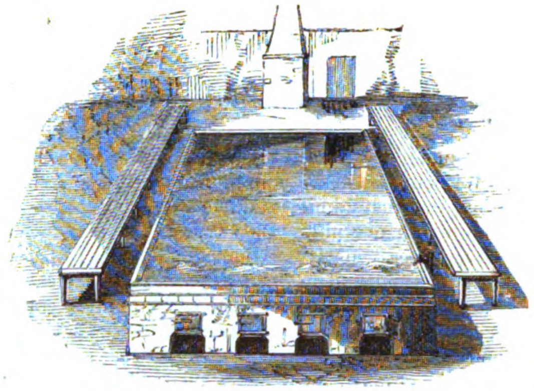
The fibres of the cotton within the flame are charred by the heat, but not burnt, on account of the absence of air; so that it is necessary to get rid of the accumulating wick by means of snuffers. In composite candles, however, the wick is plaited, so that the end bends considerably, and is thus brought out of the flame and consumed, a plan which could not be adopted with tallow on account of the guttering.

In the combustion of oil in a lamp, similar changes to those which take place in the flame of a candle go on. The oil is drawn up into the flame by capillary attraction, and is converted into a gaseous hydro-carbon. It is of no consequence to the theory whether the wick be a solid bundle of fibres or a thin circular band. The antique lamp of the ancients, however we may admire it for its grace and beauty of form, must have been a smoky, badly-smelling utensil; but the solid wick continued in use until the year 1789, when a Frenchman, named Ami Argand, invented the lamp which still perpetuates his name. This was a grand improvement in artificial illumination: its most important features were the disposing of the wick in the form of a ring, and inclosing the flame within a glass chimney. By this means a double current of air was supplied, as shown in fig. 523; one current setting in from the bottom of the glass and feeding the air on the outside of the ring of flame, and the other current setting in through the apertures at the bottom of the well, and passing up through the interior of the ring. It must not, however, be supposed that by this arrangement flame ceases to be a luminous bubble of gaseous matter: the form only is changed, since in the Argand lamp we have a couple of concentric luminous rings, the space between them being filled with inflammable vapour, where no combustion is going on.

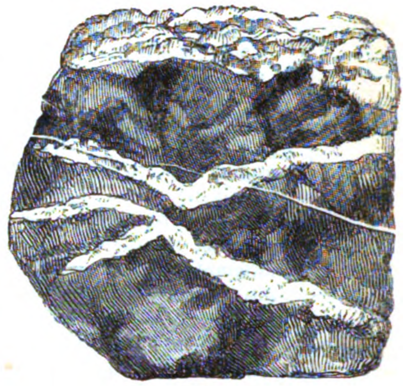
In a gas flame the gaseous hydro-carbon is prepared beforehand, stored up in vessels, the pressure of which keeps up a constant supply to the burner. Gas has been prepared by the distillation of tallow or of oil; but in a country abounding in bituminous coal (which is used, we think, with so much unwise extravagance), that material would be the cheaper source. A ton of Newcastle coal yields about 9,250 cubic feet of gas, and about thirteen cwt. of coke. The coal is distilled in *retorts*, or hollow flattened cylinders of iron or of clay, fig. 524, No. 2 or No. 3 being preferred. The retorts are set in stacks of three or five, arranged in long brick furnaces (fig. 526); the mouths of the retorts project from the furnace, and are fitted with movable lids, which can be closed air-tight by a clay luting, and fixed by means of a screw, W, fig. 525, and a holdfast, V. Another mode of securing the mouth is shown in fig. 531. The retorts R are shown more clearly in their position in the furnace F, at the left hand of the general arrangement shown in fig. 534. From the upper part of the mouth of each retort, fig. 531, is a socket for the reception of a tube which passes up some way, and then bends into a long,



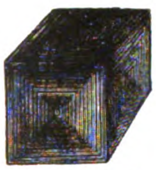
539 ROOFING SALT.



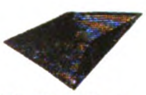
540. EVAPORATING PAN.



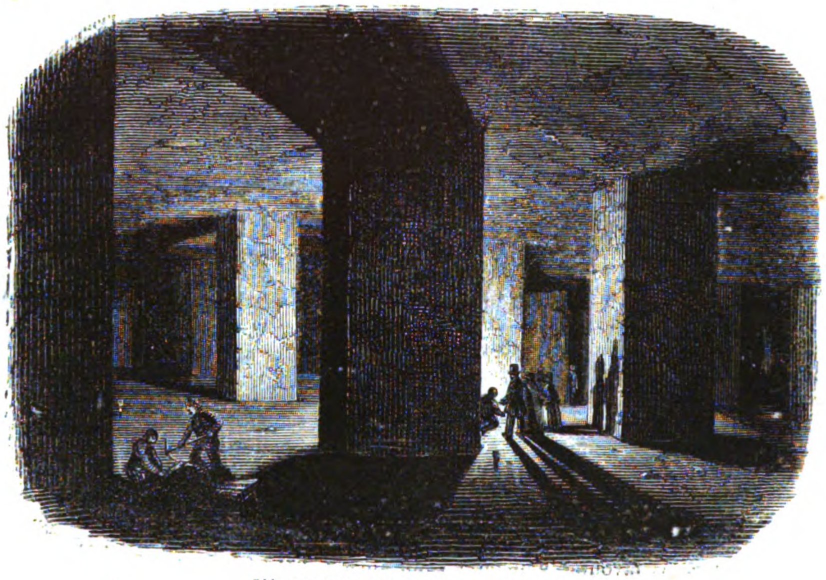
541. ROCK SALT.



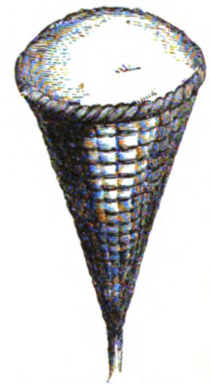
542. CRYSTAL OF SALT.



543. PORTION OF CRYSTAL.

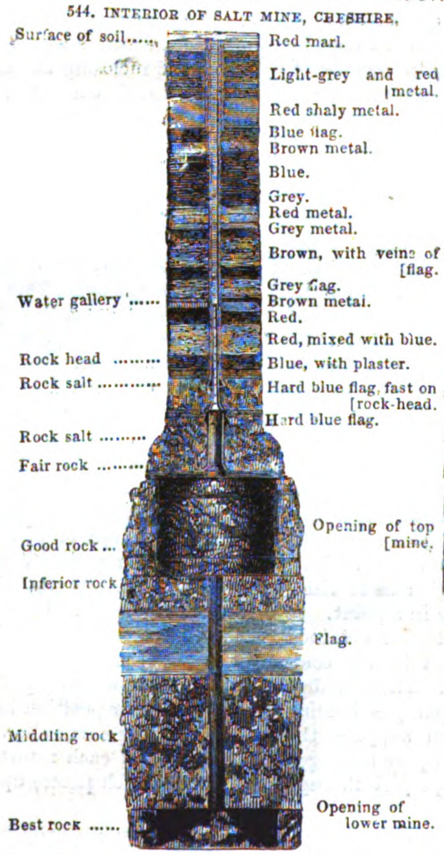


544. INTERIOR OF SALT MINE, CHESHIRE.

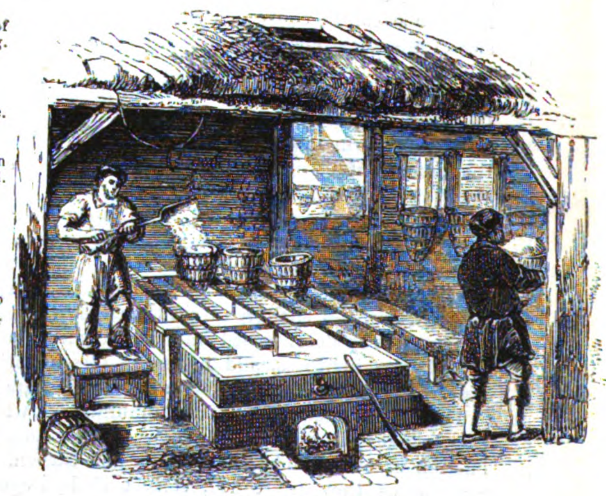


545. DRAINING SALT.

546. SALT-PAN ON THE FORTH.

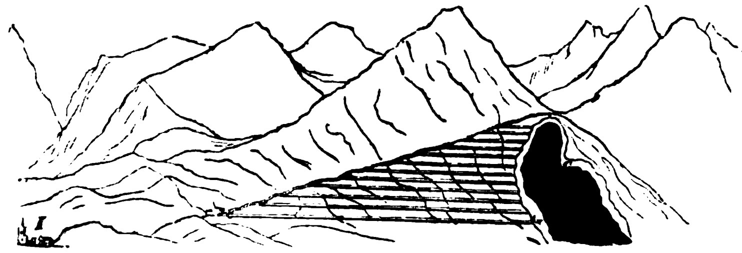


547. SECTION OF THE WHARTON SALT MINE, ON THE RIVER WEAVER, CHESHIRE.



548. SALT PAN.

549. DEPOSIT OF ROCK SALT IN WIRTEMBERG.

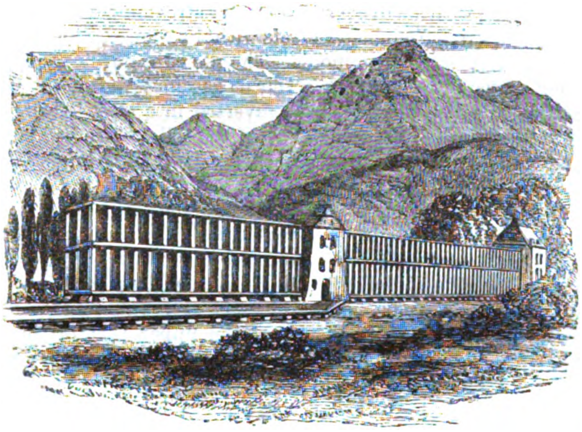


550. METHOD OF WORKING SALT AT ISCHL.

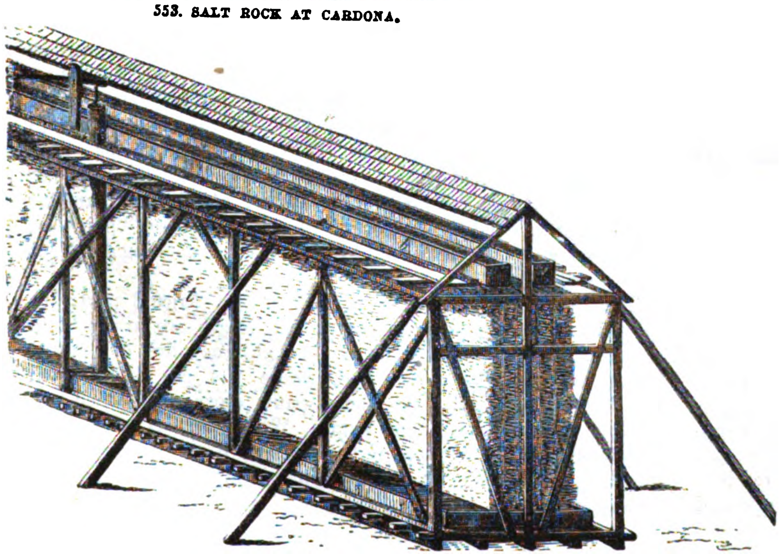
551. ISCHL.

552. HALL.

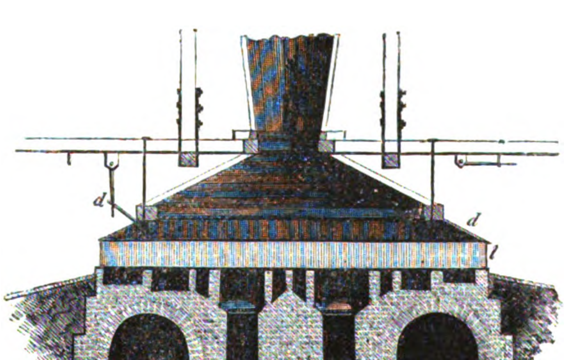
553. SALT ROCK AT CARDONA.



554. THORN-HOUSE AT MOUTIERS.



555. METHOD OF EVAPORATING BRINE IN SAXONY.



556. EVAPORATING PANS.

wide pipe, called the hydraulic main, H, fig. 534, which passes horizontally along the front of the whole range of furnaces. This main pipe is kept half filled with tar and moisture derived from the coal, and in it the pipes from the retort terminate; so that they are closed by means of a water valve, which permits one retort to be cleared out and recharged, without interfering with the other retorts which are in action. As the tar accumulates in the hydraulic main, it overflows into the tar-well *t*, whence it is drawn off into a well sunk in the ground. In from four to six hours from the time of charging the retorts, the coal will have given off all its gas: the mouth of the retort is then opened, the coke is raked out into iron boxes, moving on wheels (fig. 526), and is extinguished by pouring water over it, while a fresh supply of coal is introduced by means of a long scoop, as shown in the same engraving. The mouth of the retort is instantly closed, and the distillation proceeds as before. In the mean time, the gas from the various retorts having deposited in the hydraulic main most of the tar, and some of the water and ammonia, with which it is charged, passes through a system of pipes, C, called a *condenser*, which is kept cool by water flowing over it, from a cistern, *c*. The effect of this refrigeration is to remove from the gas most of its remaining tar and aqueous vapour. The gas, however, is still too impure for use: it contains carbonic acid, sulphureted hydrogen, cyanogen, napthaline, ammonia, and some other matters, which are removed by causing the gas to pass through the lime purifiers, P, one of which is shown separately in fig. 529; only this is what is called a *dry* lime purifier, and that in fig. 534 is a *wet* one, the lime being made up into a cream with water, when it is poured into the reservoir *h*, and is agitated with the stirrer *s*. It is now common to pass the gas through what is called a *scrubber*, which consists of a tower filled with small coke, with water streaming down it; while the gas entering from below meets with the shower, which deprives it of the last traces of ammonia. The gas, after purification, passes along a pipe into a large reservoir or gasometer of metal, G, consisting of a bell of sheet iron, inverted in a tank, T, containing water, in which the gasometer rises and falls. The bell is nearly counterpoised by weights and chains passing over pulleys, W, presenting the effect shown in fig. 537. When the gasometer is full, its descent forces the gas along the main M, by which it passes to the pipes of the consumers. Gasometers are sometimes made of the form represented in fig. 532, in two or three parts: the rim of the upper part is curved upwards and filled with water, so as to form a channel and water joints for the reception of the recurved rim of the upper part of the lower portion; and the tank in which they dip is merely a ring of water surrounding a central core of masonry, M. The gasometer in its collapsed form is shown in fig. 533: the gas enters by the pipe *a*. The supply of gas to the mains requires careful regulation, since it must be varied at different hours, it being greatest when the shops are open, and diminishing as the night advances. The pressure is known by means of an *indicator* (fig. 536), which consists of a small gasometer, A, rising or falling in a tank, according as the pressure varies in the main, with which it is connected by a small pipe, B. To the upper part of the gasometer is fastened a vertical rod, C, carrying a black-lead pencil, which presses against a cylinder, D, covered with a sheet of paper, ruled so as to mark the twenty-four hours of the day. By connecting the cylinder with a time-piece, it is made to rotate on its axis, by which means the pencil draws a line opposite the hour when it is set going. If the pressure be constant for a number of hours, the line will be straight; but if the pressure vary, it will be zigzag; the amount of pressure being indicated by the horizontal lines into which the paper is divided: a new paper being added every twenty-four hours, a constant record is thus preserved of the pressure kept up on the gasometers which supply the mains. The amount of pressure is ascertained by means of a small gauge (fig. 527), consisting of a bent tube screwed into the gasometer at *b*, and open to the air at *a*. Mercury is poured in, so as to occupy the bend of the tube and to rise up a little way in each limb. If the pressure be the same within the gasometer as that of the air outside, the mercury will stand at the same height in both limbs: if the pressure be greater in the gasometer than outside, the mercury will be depressed in *b* and rise in *a*, which is the case in the present example.

In small gas-works the pressure is regulated by a self-acting instrument called the *governor* (fig. 538). *a* is a tank, in which the regulating vessel *b* floats in water; *c* is a metal cone attached to the top of *b*; the gas enters by the pipe *d*, on the top of which is a perforated plate, *i*; *e* is the outlet pipe by which the gas escapes into the street mains; *f* is a counterbalance; when this is small, the pressure is of course greater than when it nearly counterpoises the vessel *b*. When the consumption of gas from the mains is steadily maintained, the supply by the pipe *d* adjusts the vessel *b* to a certain height, and the cone *c* takes its place in the opening *i*, so as to admit into *b* a quantity of gas equal to the demand. Should the demand on the mains increase, the vessel *b*, and consequently the cone *c*, will descend a little, thus enlarging the opening at *i* and admitting more gas from *d*. If, on the contrary, the demand on the main should diminish, *b* will rise, and the cone *c* will contract the opening at *i*, thus diminishing the supply from *d*. This arrangement of the cone *c* in the opening *i* is called a *throttle-valve*.

The gas meter, by which the consumer registers the amount of gas burnt, consists of an outer case, *b* (fig. 530), more than half filled with water, and an inner drum *d*, moving round on two pivots, placed horizontally, and divided into four compartments, $a\ a'\ a''\ a'''$, by partitions, which are bent so as to form a central space *g*. The gas is supplied by a tube, *i*, and as one of the four spaces becomes filled with gas it becomes lighter, and causes the drum to turn round a quarter of a revolution; when, rising above the level of the water, the gas passes into the outer case, and up a tube at the top which supplies the burner. While one partition is rising and discharging its gas, another is being brought under the water and being filled; thus, so long as gas is being burnt, the drum *d* is revolving; and by an arrangement of wheels, hands are made to move upon dial plates, which register the number of cubic feet of gas consumed.

Fig. 528 represents a *water-valve*, which is useful for making connexions between pipes, such as those which connect the first lime purifier, fig. 529, with the second, the second with the third, &c. The floating vessel *d* has a partition *e*, which descends so as to come into contact with the water in the cistern *c*, when it is desired to shut off the supply of gas. This partition is placed between the two pipes *a b*, one of which is the inlet and the other the outlet pipe. By increasing or diminishing the counter poise *p*, the partition recedes from or approaches to the surface of the water in the cistern, and resists or retards the flow of gas from the inlet to the outlet pipe.

The arrangements for supplying gas in a large city are on an enormous scale. London and its neighbourhood are supplied by fifteen gas companies. The Westminster gas works alone are accustomed to supply as much as 5,000,000 cubic feet of gas in one night from their three stations. Gasholders have also been enormously increased in size; one such vessel being sometimes of the capacity of 1,000,000 cubic feet, or 140 feet in diameter and 70 feet in height. The counterpoise weights and chains are now dispensed with, the weight of the gasometer being sufficient for its stability.

The best form of burner is that on the Argand principle, in which the holes for the escape of the gas are arranged in a circle. Single jets without a glass chimney are of various forms, such as the *swallow-tail*, where the gas issues from two holes so inclined that the streams cross each other and produce a broad continuous flame. When the gas escapes by a narrow slit by the top of the burner, it produces what is called the *bat's-wing* (fig. 535); there are also the *fish-tail*, and some others.

XXIX.—SALT.

COMMON salt (*chloride of sodium*), which enters into the composition of bread and other kinds of food, and is eaten with meat and vegetables, is one of the necessaries of life, and is therefore supplied to us by Nature's bountiful hand in inexhaustible quantities. Every gallon of sea-water contains nearly four ounces of salt; it is stored up in the solid form in vast deposits at a moderate depth in several parts of the continent of Europe; or it is found in brine-springs, from which it may be obtained by evaporation. Some parts of the world, however, are not so favoured; as in Central Africa, where salt is described as the greatest of all luxuries, and a child sucks a piece of rock salt with as much relish as our little ones consume barley-sugar. The vast continent of America is also scantily supplied with salt: thus, trade and commerce arise from the abundance of supply on the part of one nation and its deficiency on that of another; and often by means of this intercourse a secondary advantage arises, which is of far greater importance than the primary one, namely, the preaching of the Gospel in the farthest ends of the earth.

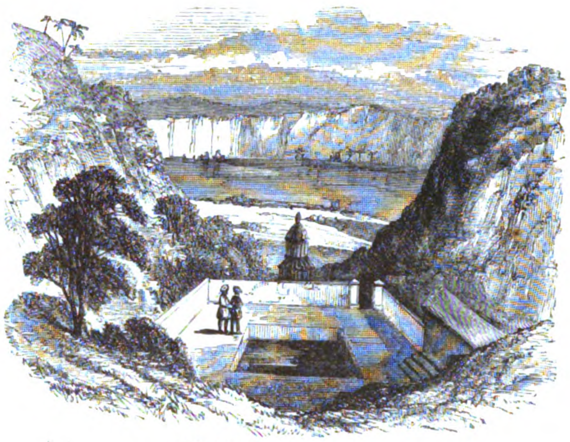
The deposit of salt among rocks of almost all ages is an interesting and important fact, not easy to account for. Some suppose the rock salt (or *sal gem*, as it is called from its beautiful gem-like appearance) to have been deposited by saline lakes, or even by the sea, which once covered and afterwards quitted the place; but the purity and solidity of the masses, their bulk, and peculiar and insulated positions, render these suppositions unlikely. Fig. 549 represents the deposit of rock salt at Whimpfen, in Wirtemberg: fig. 550 represents the deposit at Ischl, in Upper Austria, among beds of limestone rock. The deposit is worked by means of twelve horizontal galleries cut in the face of the mountain. The salt mass S is separated from the limestone by bands of gypseous marls, G. The position of the town of Ischl is shown at I, and also in fig. 551. The salt mines of the Tyrol are situated near Hall, in the valley of the Inn, fig. 552. Fig. 553 represents the salt rock at Cardona. In our own country, Cheshire is distinguished for its salt; the principal deposit occurs near Northwich, in two beds situated one above the other, separated by about thirty feet of clay and marl, intersected with small veins of salt; the two beds together are not less than sixty feet in thickness, three hundred feet in breadth, and a mile and a half in length: these beds occur in magnesian limestone. Fig. 547 shows a section of a salt mine, on the river Weaver. The strata passed through usually consist of clay and gypsum in various proportions. The workmen call the clay red, brown, and blue *metal*, according to its colour; and the gypsum they name *plaster*. Fig. 544 represents the interior of a salt mine, with pillars supporting the roof. The appearance of the roof, with portions of earth mixed with the salt, gives the effect of a rude mosaic, fig. 539; while fig. 541 represents veins of rock salt in crevices of the rock, tinged red with oxide of iron. The rock salt is contained in masses of considerable size, differing in form and purity; they are separated by the usual operation of blasting, and with the aid of miners' tools. The rock salt is raised to the surface by steam-power; but horses are employed underground for conveying the rock to the bottom of the shaft.

When water comes in contact with these deposits, brine-springs are formed; these are not uncommon in the valleys of the Weaver and the Wheelock. In using the brine for the manufacture of salt, a shaft is sunk down to it, and it is pumped up as it is wanted into evaporating pans (fig. 540); these are of wrought iron, oblong in shape, and from twelve to sixteen inches in depth; there are three or four fires to each pan. At one end of the pan-house is the coal-hole, and at the other end a chimney; along each of the two remaining sides is a walk, five or six feet wide, occupied by benches, on which the salt is placed in conical baskets to drain, after it has been taken out of the pan. The mode of manufacture is varied, according as it is intended to produce *stoved* or *lump salt*, *common salt*, *large-grained flaky*, and *large-grained* or *fishery salt*. The effect of these variations will be understood by examining a crystal of salt. The natural form of the crystals of pure chloride of sodium is that of a perfect cube (fig. 542); and they constantly assume this figure when the proper arrangement of their particles has not been interrupted by agitation, or the application of too strong a heat. Every perfect cube is composed of six quadrangular hollow pyramids (fig. 543), joined by their points and external surfaces; each of these pyramids, filled up by others, similar but gradually decreasing, completes the form. Each of these pyramids is composed of four triangles, and each triangle is formed of threads parallel to the base, which threads consist of a series of small cubes. These cubes dissolve in about three parts of cold water, and they are scarcely more soluble at a temperature of 212°.

In making the stove or lump salt, the brine is brought to a boiling heat, or 225°. Crystals of salt are soon formed on the surface, and fall to the bottom as they form. In about twelve hours most of the water has evaporated; the fires are slackened, and the salt is drawn to the sides of the pan with iron rakes. It is then placed in conical baskets (fig. 545), to drain (see also fig. 548), and the drying is completed in stoves. The pan is filled twice in the course of twenty-four hours; and impurities which rise to the surface are skimmed off before the brine boils. In making common salt, the pan is filled but once in the course of twenty-four hours. The brine is first brought to a boiling heat, when the fires are slackened, and the crystallization is carried on at about 160° or 170°. The salt forms in pyramids of close compact texture, clustered together, with cubical crystals intermixed. The large-grained flaky salt is crystallized at 130° or 140°, and the pan is filled once in forty-eight hours. This salt is somewhat harder than common salt, and approaches nearer to the natural form of the crystals. In making the large-grained or fishery salt, the brine is heated to 100° or 110°, so that the crystallization proceeds more slowly than in making the other kinds: the salt forms in large cubical crystals, and five or six days are required to evaporate the brine. The reason why the large-grained salt is better fitted than small-grained salt for the *packing* of fish and other provisions is, that the large crystals, from their hardness and compactness, retain their solid form longer, and are very gradually dissolved by the fluids which exude from the provisions; thus furnishing a slow but constant supply of brine. But in preparing the pickle, or *striking* the meat, by immersion in a saturated solution of salt, the smaller-grained varieties are to be preferred, on account of their greater solubility.

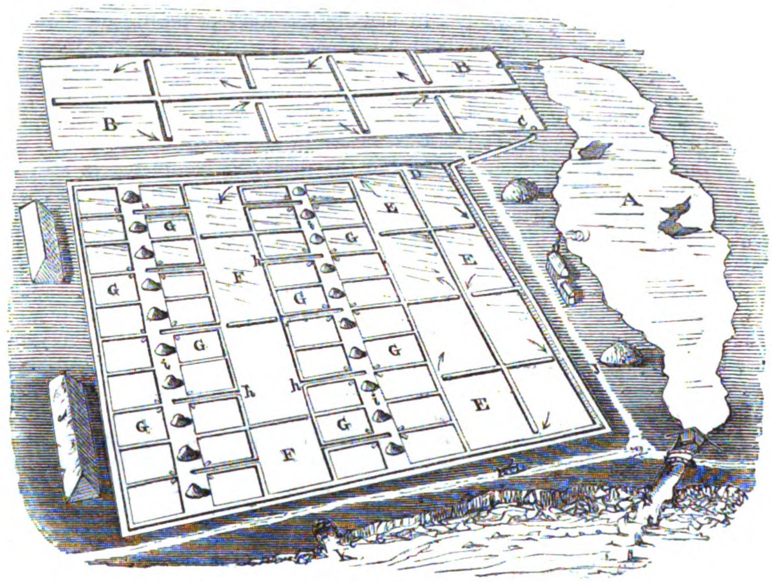
Natural salt springs are usually only slightly impregnated with salt; but there are many inland situations where the cost of carriage renders the importation of salt very costly, so that it is advantageous to obtain a supply from the weak brine of these springs. But as the cost of fuel might become a more serious charge than that of carriage, successful attempts have been made to evaporate the brine in the open air, so as to concentrate it before it enters the evaporating pan. Thus, at Moutiers, in Sardinia, the strongest spring contains less than two per cent. of saline matter, and in most of them only one pound and a half of salt can be obtained from thirteen gallons of water. In order to concentrate it by natural evaporation, the weak brine is spread over as large a surface as possible, since the rate of evaporation depends on the temperature and the amount of surface exposed. The evaporating houses (fig. 554) are each 350 yards inl ength, twenty-five feet in height, and seven feet wide. They consist of a frame of wood filled with double rows of fagots of black-thorn

557. PILLAR OF SALT.

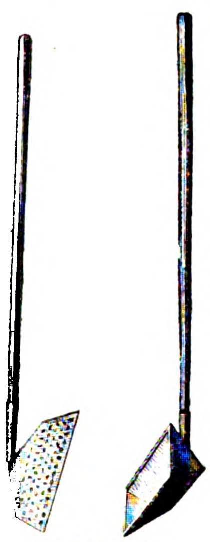


558. SALT LAKE IN INDIA.

559. WADY MOJEB.

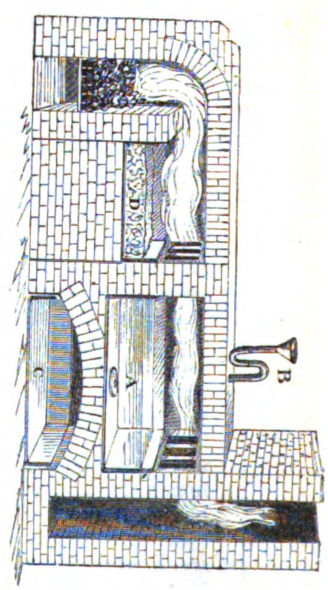


561. SALTERN.



560. SALT TOOLS.

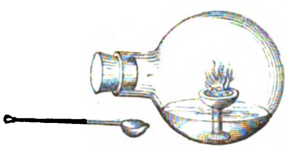
562. SHORE OF THE DEAD SEA.



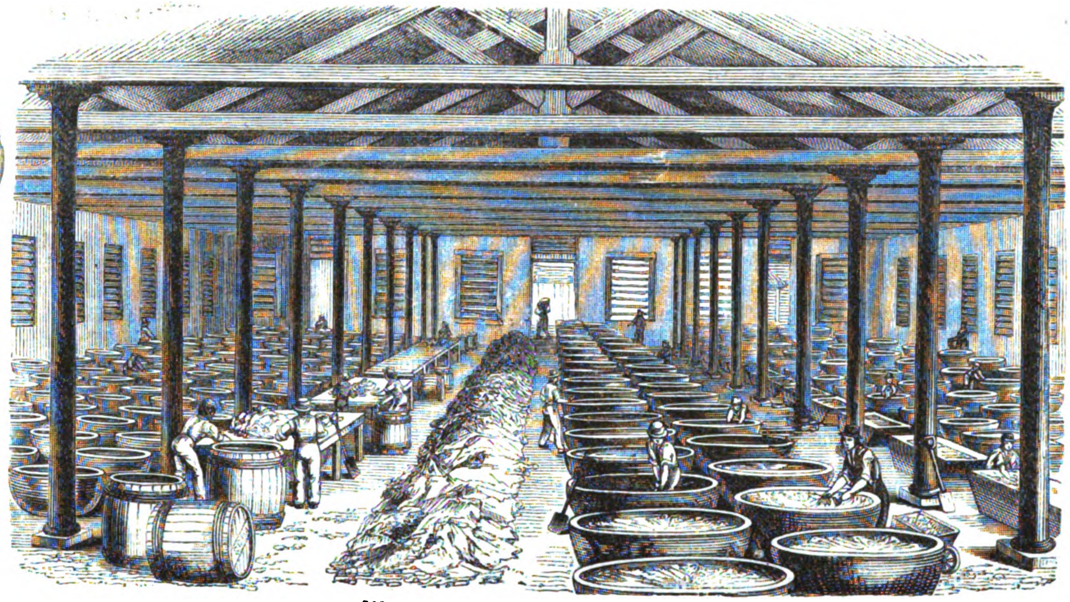
563. SODA FURNACE.

564. SODA FURNACES.

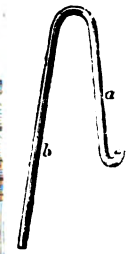
565. BLACK-ASH VATS.



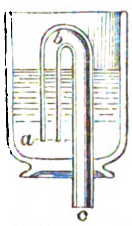
567. SULPHURIC ACID GLASS.



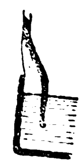
566 SODA CRYSTALLIZING HOUSE.



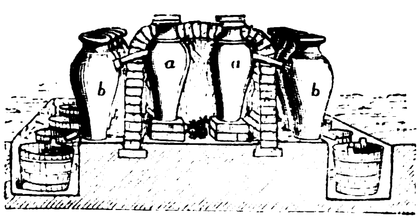
569. SYPHON.



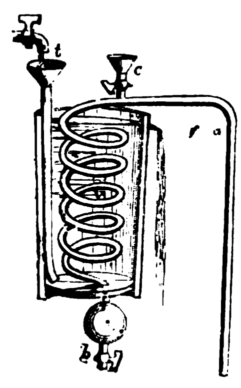
568 SYPHON-CUP.



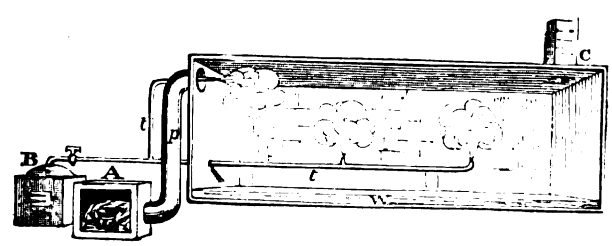
570. OPENING.



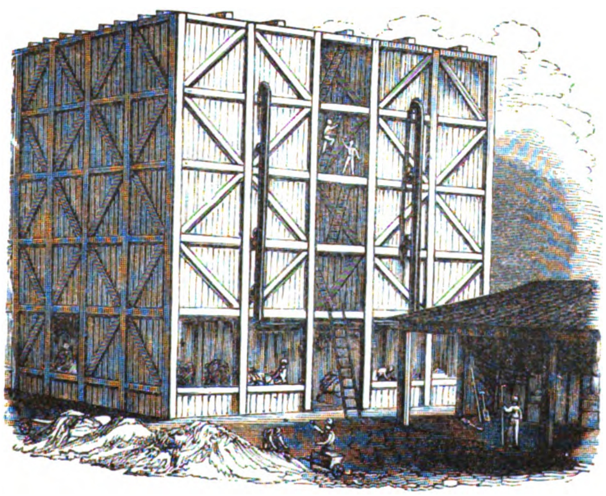
571. DISTILLING SULPHUR.



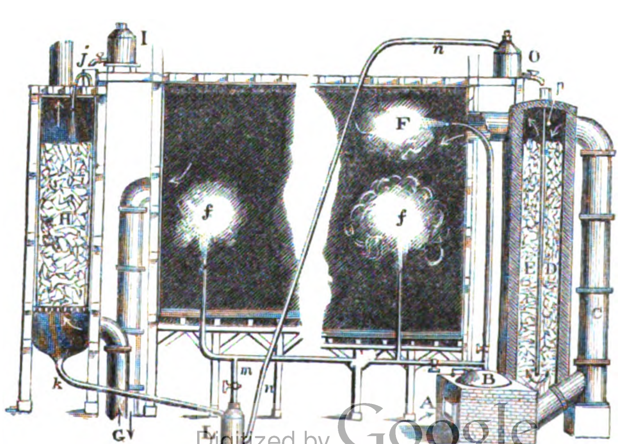
572. WORM-SYPHON.



573. SULPHURIC ACID CHAMBER.



574. SULPHURIC ACID CHAMBERS.



575. SULPHURIC ACID CHAMBER.

(whence these houses are called *thorn houses*); and in the midst is a stone building containing a hydraulic machine for pumping the water to the top of the building, whence it passes into canals on each side, which extend the whole length of the building; from these canals it passes into smaller channels, from which it trickles through a multitude of small holes in a very gentle shower upon the fagots, where it is divided into an infinite number of drops, falling from one point to another. The evaporating surface is thus indefinitely enlarged; and as the thorn house is placed so as to catch the currents of wind that rush down the valley, the amount of evaporation is very large. By repetitions of the process the water is at length nearly saturated, and is then passed to evaporating pans, where the salt is crystallized in the usual manner.

The arrangement at the Saxon salt works is similar to the above, and will be understood by reference to fig. 555; in which *t* is the wall of black-thorn fagots, covered by a roof, *r*, the greater portion of which, however, is removed in the engraving in order to show the details; *b* is one of the canals supplied with brine from the upper reservoir, and *c* is the perforated channel from which the brine falls drop by drop upon the fagots. The process can be repeated by pumping the brine up from the lower tank. The brine which is concentrated or *graduated*, as it is called, during the fine season, is stored up in vast reservoirs of masonry, where it deposits impurities. The boiling is carried on during the winter months only; the evaporating pans (fig. 556) are furnished with a roof-shaped hood of boards, with a trunk at *s* for carrying off the steam, and shutters at *d*, which can be turned back or closed according to the weather. The vapour that escapes from the surface of the brine contains about one per cent. of salt; and the portion that condenses and trickles down the sides of the chimney *s* is collected in a channel, *t*, and conveyed to a tank.

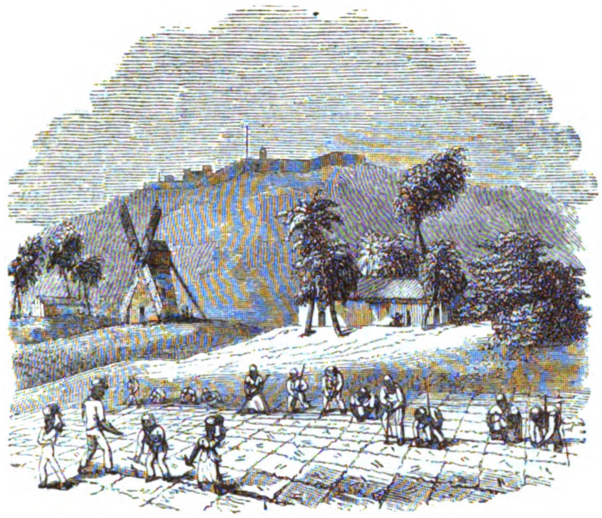
Salt lakes in some parts of the world are used as a source of salt. In the steppes of Asiatic Russia salt lakes are numerous, and their waters hold so much salt in solution that the action of the summer heat is sufficient to crystallize a portion of it; and the crystals, being carried to the banks by the action of the waves, form immense shoals of salt. The Dead Sea (fig. 562) contains a larger proportion of salt than the waters of the ocean. When agitated by wind, the surface has the appearance of foaming brine; and the spray, evaporating as it falls, leaves incrustations of salt upon the clothes, and coming in contact with the skin produces a pricking sensation, and is painful to the eyes, nostrils, and lips. The northern shore is very barren; branches and trunks of trees are scattered about, some charred and blackened, others white with an incrustation of salt. The water is also described as being greasy to the touch. On the southern shore, in the neighbourhood of Usdom, is a pillar of solid salt (fig. 557); it is capped with carbonate of lime. Fig. 559 is one of the ravines at the southern end of the sea.

Sea-water is a convenient source of salt to persons residing on or near the coast. The saline matter of sea-water varies from three to four per cent., and of this quantity common salt forms nearly two-thirds. An economical method of evaporating the water is by means of *salt gardens* or *salterns* (fig. 561), which are laid out upon a clay soil on the coast, and worked during the summer months, from about March to September. In these salterns the sea-water is exposed in a series of shallow ponds to the action of the sun and of the air; and as the water is evaporated, the salt is deposited in the hindermost pools, while the foremost ones receive fresh supplies of sea-water. The collecting pond A is filled at the flow of the tide by means of a flood-gate, and the water, having deposited its mud, is conveyed by a pipe to the first series of pools, B; from these, by means of a channel, *c*, it is circulated through a canal, which passes round the remaining pools. From this it enters at D into the ponds at E, then into F, and, lastly, through the open channel *h*, to a third series of ponds, G. During all this time evaporation has been going on, and salt begins to form in the hindermost of these reservoirs. When a crust of salt has formed on the surface G, it is collected by means of rakes into small heaps, *i*, on the sides. When no more salt separates by crystallization, the lye is allowed to run through K into the sea. The chief impurity of the salt thus collected is chloride of magnesium, which absorbs moisture and flows off; for which purpose the smaller heaps, *i i*, are made up into larger heaps, J, and these are thatched with straw and left for a time. The tools used in forming these heaps are shown in fig. 560. Since the duty has been taken off salt, the Cheshire manufacturers have been able to produce the article at so low a price that salterns cannot compete with them. In the year 1856, the quantity of salt exported amounted to 29,820,481 bushels, of the declared value of 401,240*l.* sterling. In 1859, the official return is entered under *tons*, of which 563,280, of the declared value of 253,575*l.*, were exported.

XXX.—SODA.

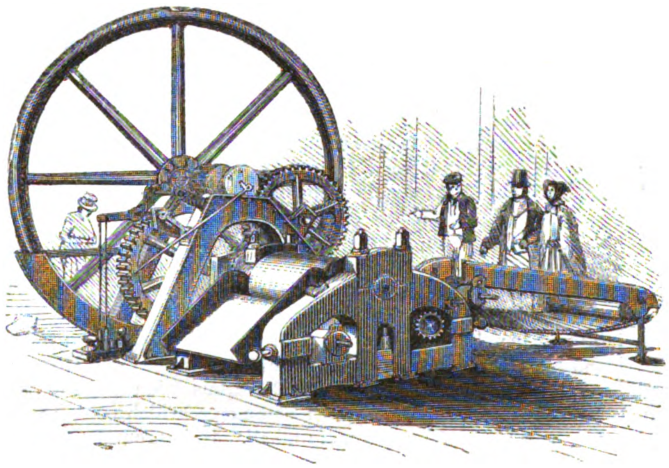
The enormous demand for common salt for curing provisions, and for giving a relish to our food, does not cease with those uses. Great quantities of salt are used in furnishing chlorine to bleaching powder; and still larger quantities in the production of carbonate of soda, which enters into the composition of glass, of soap, and of several other chemical manufactures.

Between the years 1805 and 1823 there was a duty of 15*s.* per bushel on common salt, so that its use was limited almost entirely to the purposes of food. Most of the carbonate of soda was then obtained from *barilla*, an ash produced by burning marine plants. For this purpose the *salsola soda* was largely cultivated on the southern coast of Spain, as was the *salicornia* on the southern coast of France: while on the coasts of Ireland, and the western coasts and islands of Scotland, an inferior article, named *kelp*, was produced by burning the *Fucus vesiculosus* and other species of fucus. The repeal of the duty on salt placed that abundant article in the hands of the chemist, who soon discovered a method of decomposing it, so as to get rid of the chlorine and retain the soda. The first part of the process consists in converting common salt into a rough sulphate of soda. This is done in reverberatory or *decomposing* furnaces, a number of which are arranged side by side (fig. 564), all discharging their flues into a tall chimney. The interior of one of these furnaces is shown in fig. 563. In the division A, called the *decomposing bed*, the salt and the sulphuric acid are brought together: the charge of salt may be from five to six cwt., and an equal weight of sulphuric acid (not concentrated, but of the specific gravity 1·6) is slowly poured in through a leaden syphon funnel, B; the mixture is stirred up with an iron rake covered with sheet lead, and on the application of a gentle heat abundant fumes of hydrochloric acid are liberated, which, passing up the chimney, are discharged into the air in the form of a white cloud of acid, which rains sterility on the adjacent country. Of late years, however, these acid fumes have been made to pass through towers filled with coke, through which water is constantly trickling; the hydrochloric acid, which is very greedy of moisture, is thus absorbed and got rid of. In the bed A of the furnace, about half the hydrochloric acid is expelled from the salt. The pasty mass thus produced is pushed out through an opening into a vault C, and another charge is introduced into A. The pasty mass is now removed from C into the other compartment of the furnace nearest the fire, called the *roasting bed* D, where it is exposed to a much higher temperature, and in an hour or two loses its remaining hydrochloric acid. The mass is now called *salt-cake*, and it is raked out of D to make room for another charge. The object of the next process is to convert the salt-cake or sulphate of soda into carbonate of soda; which is done by heating it to redness with coal or charcoal and carbonate of lime. The salt-cake is therefore mixed with chalk and powdered coal in the proportion of three parts sulphate of soda, three of chalk, and two of coal; and is thrown in quantities of about 2½ cwt. at a time into a reverberatory furnace, called the *black ash furnace;* which is oval in shape and divided into two parts, one of which, the farthest from the fire, called the *preparing-bed*, is higher than the second division, called the *fluxing-bed*. When the charge is sufficiently heated, it is transferred from the one to the other; and towards the end of the process the mass melts, and appears to boil, from the escape of carbonic oxide gas, which burns with a greenish or yellow flame, forming what the workmen call *candles*. At length, after briskly stirring, the mass is completely fused, and is raked out into cast-iron troughs or wheelbarrows, where it becomes solid, and forms what is called *ball-soda* or *black ash*. It contains about twenty per cent. of pure soda, mixed with unburnt coal, and a compound derived from the sulphuric acid of the salt-cake and the calcium of the chalk (lime, which is the basis of chalk, being an oxide of calcium), called oxy-sulphide of calcium. This last-named substance, known to the manufacturer as *soda-waste*, is a worthless bulky substance, constantly accumulating in the neighbourhood of alkali works, and rendering it necessary to purchase land merely to accommodate it. A cheap method of recovering the sulphur from it would be a great boon to the manufacturer. In order to extract the salts of soda from the black ash, it is broken up into coarse fragments, and digested with warm water for six hours in vats furnished with false bottoms (fig. 565); and the washing is carried on until the soluble matters are extracted, the last washings being used for acting upon fresh portions of black ash. The solution thus formed is allowed to settle, and is then pumped up into large shallow iron pans for evaporation. Heat is applied, and a good deal of the salt crystallizes during the boiling, and is removed by means of perforated ladles. To convert the caustic soda contained in the solution into carbonate, it is evaporated to dryness, mixed with sawdust, and roasted in a furnace called the *white-ash furnace*. Most of the sulphur escapes in the form of sulphurous acid; and the residue yields the soda ash or alkali of commerce, which contains about fifty per cent. of pure caustic alkali. It is ground under millstones, and is sufficiently pure for most of the manufacturing applications of soda; but for the manufacture of plate glass, and for furnishing crystals of carbonate of soda, the ash is further purified by being again calcined at a moderate heat. The carbonate thus obtained is re-dissolved; the liquid is allowed to settle, and while hot is run into hemispherical pans (fig. 566) of cast iron. In the course of five or six days, large well-formed crystals appear; these are broken up, and the *mother-liquor*, or that portion which refuses to crystallize, is allowed to drain off by withdrawing a plug in the bottom: this is evaporated to dryness, and the residue, containing about thirty per cent. of alkali, is fit for use in the manufacture of crown glass and of soap.

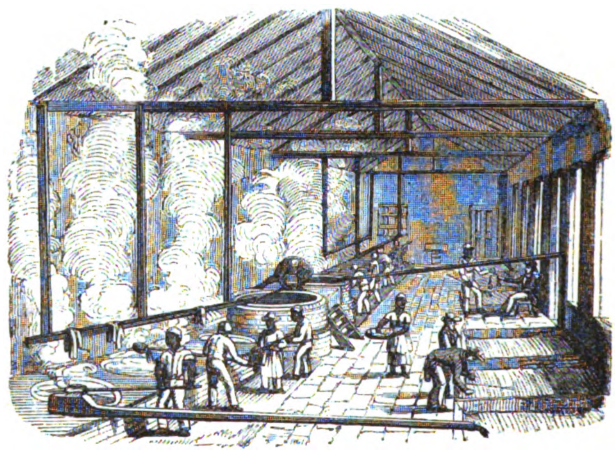


576. PLANTING THE SUGAR-CANE.

577. THE CANE HARVEST

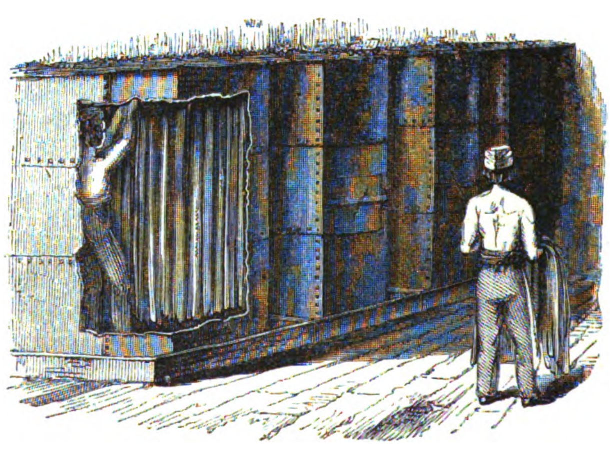


578. CANE-MILL.

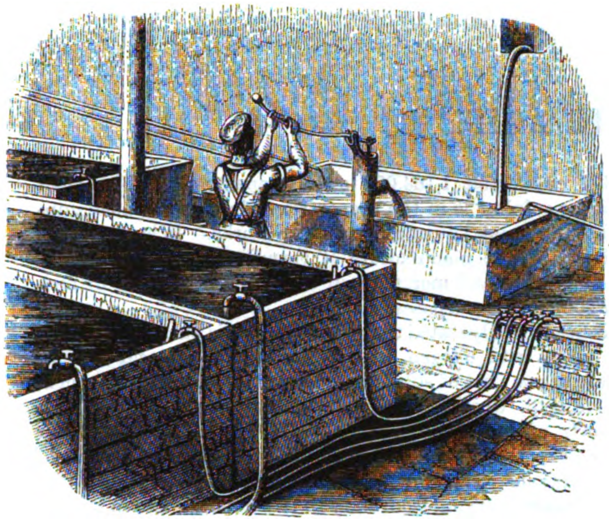


579. THE BOILING-HOUSE.

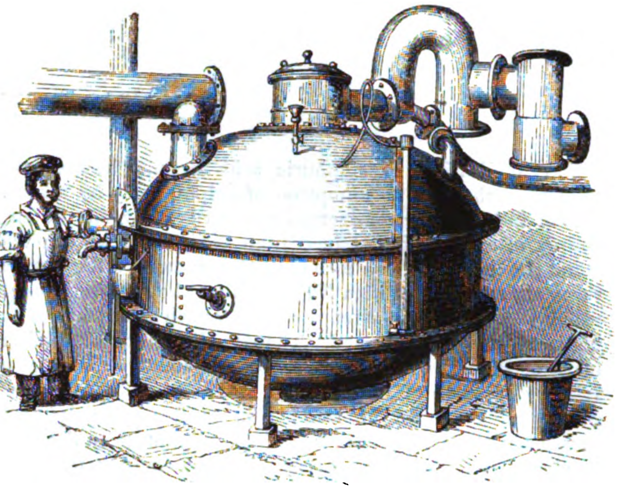
580. BLOW-UP CISTERNS.



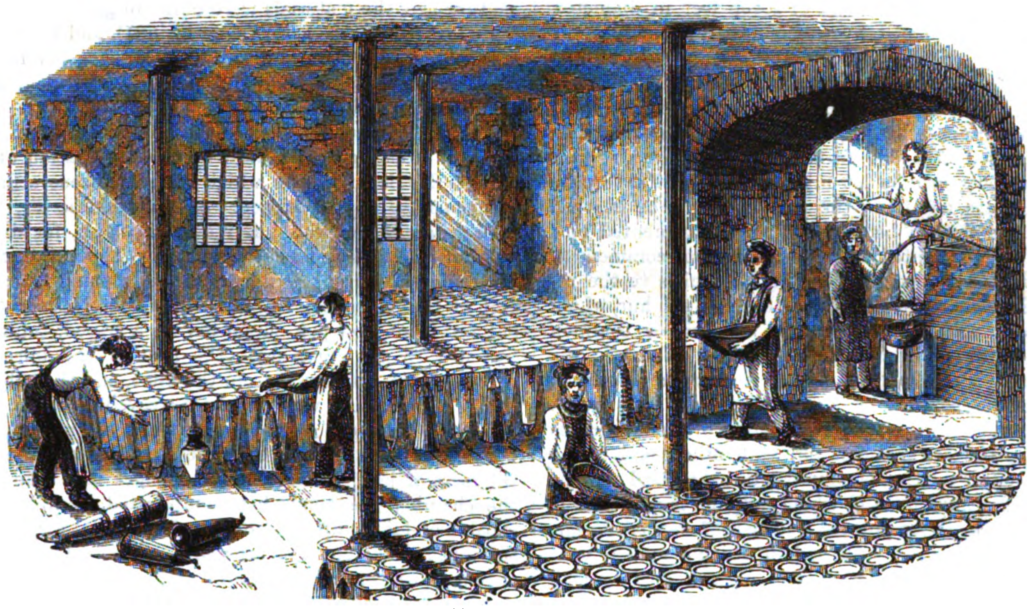
581. BAG FILTERS.



582. CHARCOAL FILTERS.



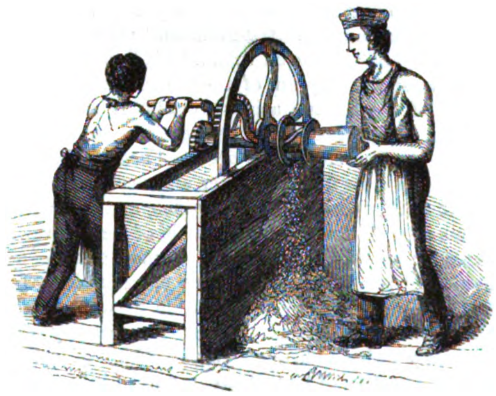
583. THE VACUUM PAN.



584. THE FILL-HOUSE.

585. SUGAR OVEN.

586. PROOF STICK.



587. TURNING OFF.

XXXI.—SULPHURIC ACID.

The applications of sulphuric acid in manufactures are so numerous, that the consumption of sulphur may be taken as a sort of index of our commercial prosperity. By far the largest supply of sulphur is obtained from Sicily; and we can understand the motives which made our Government, a few years ago, threaten to go to war with Naples, unless the sulphur monopoly, which that Power had attempted to establish in the face of existing treaties, were abolished. There is abundance of sulphur in many of the mineral productions of this country; such as gypsum, or sulphate of lime; heavy spar, or sulphate of baryta; galena, or sulphuret of lead; iron pyrites, or sulphuret of iron, &c.; but it is cheaper to import sulphur from Sicily than to obtain it from these sources. In that country, it occurs in the *native* or uncombined state, in beds of a blue clay formation, occupying the central half of the south coast, and extending inwards as far as the district of Etna. The excavations made for getting out the sulphur resemble a quarry: the fragments of sulphur, as they are got out, are collected into a heap and melted in furnaces resembling cauldrons, six or seven feet in diameter, and four or five feet in depth, by which means the sulphur is separated from the clay, calcareous stones, and gypsum, and while in a liquid state is run into wooden moulds of the form of a large brick. The crude sulphur is more economically distilled in the furnace represented fig. 571. Two rows of earthen pots, *a a*, are arranged in a close furnace upon supports, so that the necks of the pots can be let into the top of the furnace while the mouths are left free; the pots can thus be charged from the outside, and then be closed with lids cemented on; after which the fire is lighted and the distillation commences. The vapours of sulphur pass over by the side tubes to the receivers, *b b*, outside, where they condense to liquid sulphur, which flows into tubs of water. *Stick* or *roll* sulphur, or common *brimstone*, is chiefly obtained during the roasting of copper ore, or from iron pyrites; the fumes being received into a long brick chamber, where the sulphur is deposited: it is afterwards purified by being melted in pots, in which some of the impurities rise to the surface and are skimmed off, while others sink to the bottom, and the purer portion is poured into cylindrical moulds of beechwood. The third form in which sulphur is met with is that of a harsh, yellow, gritty powder, known as *flowers of sulphur*. It is obtained by *sublimation*, a process in which a solid is converted into vapour by heat, and then suddenly solidified by cold. It differs from distillation, in which the vapour distilled is condensed by cold into a liquid. Flowers of sulphur are prepared by heating crude sulphur in a vessel which communicates with another of large capacity, such as a chamber of brickwork, the walls of which being kept cool, and the process conducted slowly, the sulphur condenses in powder.

When sulphur is heated in the air to the temperature of between 450° and 500°, it burns with a blue flame, and, combining with a portion of the oxygen of the air, gives off pungent suffocating fumes of sulphurous acid. At 239° it melts, forming a yellow liquid: on increasing the temperature, its colour changes to yellowish brown, and at last becomes nearly black and opaque. At 350°, it loses its fluid character, and becomes thick and pasty. At about 500°, it once more liquifies, and if poured into water it forms into a ductile mass, capable of being drawn out into long threads: at this temperature, it may also be used for making casts and receiving impressions of seals, &c. It boils at about 824°. Sulphur is quite insoluble in water; but boiling oil of turpentine dissolves it. The specific gravity of sulphur is 1·95, or nearly twice as heavy as its own bulk of water.

The quantity of brimstone imported into the United Kingdom in the years 1857, 1858 and 1859, amounted to 987,811 cwts., 1,156,476 cwts., and 1,164,099 cwts. respectively. The chief demand for sulphur is in the preparation of sulphuric acid, gunpowder, lucifer matches, rockets, and fireworks. It is also used in medicine, in the manufacture of vermilion (which is a compound of sulphur and mercury), in bleaching straw and flannel, and for some other purposes.

It has been already stated that when sulphur is burnt in the open air, it unites with oxygen, and forms sulphurous acid; or, in other words, one part of sulphur unites with two parts of oxygen. Sulphuric acid, which consists of one part sulphur united with three parts of oxygen, is not so easily produced: in fact, in order to make the sulphur, in burning, take up three instead of two proportions of oxygen, extensive chambers or houses (fig. 574) are erected, varying from sixty to two hundred feet in length, and of proportionate height and width. The chambers are lined internally with sheet lead, that being one of the few substances which are not corroded by sulphuric acid at ordinary temperatures. When sulphuric acid was first manufactured, about a century ago, the materials were burnt in glass receivers, containing a few pounds of water (as in fig. 567), and the acid produced was sold at about two shillings and sixpence per lb. It is now made in the vast chambers already referred to, and is sold for less than a farthing a pound.

Four substances are used in the production of sulphuric acid: 1. Sulphurous acid, produced by the combustion of sulphur in air. 2. Nitric acid, from which the sulphurous acid obtains an additional supply of oxygen. 3. Atmospheric air, which must be constantly renewed. 4. Water or steam, for dissolving the sulphuric acid as fast as it is formed. The sulphur which supplies the sulphurous acid is burnt in a small furnace A, at one end of the chamber, fig. 573: immediately over the burning sulphur is an iron pot, supported on a tripod, containing nitre, mixed with sulphuric acid: the heat of the burning sulphur drives off the nitric acid from the nitre, and the sulphurous acid and the nitric acid vapours are conveyed into the chamber by the wide tube *p*. At the same time, steam supplied by the boiler B is conveyed by the tube *t*, and enters the chamber in the form of jets. The chemical changes that take place within the chamber are somewhat complicated. Sulphurous acid is capable of taking up more oxygen from moist air, and of forming sulphuric acid; but the process is a very slow one. It takes oxygen, however, rapidly from nitric acid (nitrogen + 5 oxygen), and reduces it to the state of nitric oxide (nitrogen + 2 oxygen), a gas which, by mere exposure to the air, takes up an additional supply of oxygen, and forms nitrous acid (nitrogen + 4 oxygen). Now it is remarkable that the sulphurous acid readily takes an additional supply of oxygen from this nitrous compound in the presence of moisture; so that two more portions of sulphurous acid thus become converted into sulphuric acid, and the nitrous compound is brought back to the condition of nitric oxide, in which it is again fitted to rob the atmospheric air of its oxygen, and thus to continue the action. Hence the nitric oxide becomes a carrier of oxygen, continually taking it from the air of the chamber, and giving it up to the sulphurous acid, so that a comparatively small quantity of nitre is sufficient to convert sulphurous into sulphuric acid. The nitrogen of the atmospheric air is discharged by the chimney C, while the sulphuric acid, condensed by the steam, accumulates on the floor of the chamber W. A sample of the acid may be taken out by making an opening in the side near the bottom of the chamber, by pushing the lead inwards, and prolonging it so as to dip beneath the surface of the liquid (as in fig. 570), and prevent the escape of gas. As the waste products of the chamber, in escaping by the chimney C, fig. 573, take with them some of the valuable nitrous

compounds, arrangements have been made for retaining them by passing them through a refrigerator immersed in a tank of water at G, fig. 575, from whence they ascend into tall, cylindrical chambers, H, filled with coke, and resting on a grating below, so that the gas has to filter through it before it escapes into the atmosphere. The coke is kept constantly wet with strong sulphuric acid, supplied from the reservoir I. The coke is kept wet by a sudden gush of liquid, which is renewed at regular intervals by allowing a constant stream from I to flow into *j*, which is shown on a larger scale in fig. 568. Here the syphon *a b c* has its longer limb passed through the bottom of a cup, so that in filling the cup no liquid will run out until it rises above the bend at *b*, when the liquid in the cup will flow out at a gush, until it is reduced to the level *a*. This intermittent flow of acid, trickling down through the column H, absorbs nearly all the nitrous compounds which escape from the chamber, so that scarcely anything but pure nitrogen is discharged into the air: the acid then flows down the small pipe *k* into the receiver L, from whence it can be raised into the reservoir O simply by admitting high-pressure steam from the pipe *m* into L, when the acid is pressed up the pipe *n* into O. From O it is made to flow by another syphon cup, similar to fig. 568, into other columns of coke D, E, where it meets with the fresh sulphurous acid gas generated in the furnace A, on its way to the first chamber. The effect of this is to separate the nitrous compounds from the acid which is trickling down through the coke. In order to delay the passage of the sulphurous acid, the column of coke is divided by a stream, so that the sulphurous acid generated in A passes up C, down the column D, up the column E, and so into the first chamber, where it meets the jet of steam F, generated in the boiler B. In fig. 575, the ends of the first and last chambers only are shown, the intermediate chambers being omitted; *f f* also represents jets of steam.

During these complicated changes, the sulphuric acid continues to be formed, and to trickle down the sides of the chamber to the bottom, gradually increasing in density. When the specific gravity of the acid has reached 1·450 (or, in other words, when a bottle which holds 1000 grains of pure water, being filled with the acid, such acid weighs 1,450 grains), it is drawn out of the chambers, and evaporated in shallow leaden pans, until, by throwing off a portion of its water, its density is 1·720. In order further to concentrate the acid, it must be heated in glass or platinum retorts, until white fumes of the acid begin to appear. It is now a dense, oily-looking, colourless liquid, of the specific gravity 1·842. It has no smell; but, from its powerful attraction for moisture, it chars and blackens most organic substances that it comes in contact with. When mixed with water it becomes exceedingly hot, from the condensation that takes place; the two liquids occupying less space than they did before being mixed. If a portion of the acid be exposed to the air in a shallow dish for a few days, it will double its weight by absorbing moisture. The acid is removed from the retorts by means of a lead syphon (fig. 569), in which the end of the shorter arm *a* is turned up: this syphon is first inverted and filled with water; and the long end *b*, being closed with the finger, the short limb is inserted into the body of the retort. On removing the finger, the water in the syphon is set in motion, bringing after it the acid: the water is caught in a small cup, which is removed the moment the acid begins to appear. It falls into the vessel placed for its reception, in a smooth, quiet stream, resembling oil; whence originated the old name of *oil of vitriol*, applied to this acid (the vitriol being sulphate of iron, a vitreous looking salt of a green colour, the old name for which was *green vitriol*). The acid is transferred to large globular green glass bottles, called *carboys*, packed in straw in wicker baskets, and thus sent to the market.

In large works, it is found more economical to concentrate the acid in stills made of the metal platinum than in glass stills, which are liable to break by the heat, and entail loss of acid, and danger to the operatives. A platinum still, with its appendages, will cost about 80,000 francs, or 3,200*l.* sterling (for these stills are nearly all made in Paris). When the acid is sufficiently concentrated, it is removed by means of the syphon, fig. 572. The leg *a* is plunged nearly to the bottom of the still, the stop-cock *b* is closed, and the worm is filled with cold acid through the funnel C. The stop-cock to this funnel is then closed, and *b* suddenly opened, when the acid thus set in motion draws out the contents of the still. The acid is cooled by keeping the worm immersed in cold water, a supply of which is introduced into the vessel V, by the pipe *t*, which supplies the colder and heavier water to the bottom of the vessel: while the water heated by the worm escapes at the opening *f*.

XXXII.—SUGAR.

SUGAR is a common product of the vegetable kingdom, and forms an article of nutriment to most plants at some period of their growth. There are four principal varieties of sugar, the most important of which is *cane* sugar, the ordinary product of the sugar cane. The second, known as *fruit* sugar, is the principle of sweetness, in most acidulous fruits ; it does not crystallize like cane sugar, but forms a syrupy liquid, which is abundant in treacle. The third variety, known as *grape* or *starch* sugar, is often formed from the second variety, and may be noticed in old dried fruits, such as raisins and figs, where it forms in hard granular sweet masses : it may also be prepared artificially by boiling starch with a dilute acid. The fourth variety, known as *milk* sugar, is that to which milk owes its sweetness. These varieties of sugar consist of nothing more than charcoal and water in a state of chemical combination: thus, cane sugar contains 72 parts of carbon and 99 of water ; fruit sugar contains the same quantity of carbon and 108 parts water ; while in starch sugar there are 126 parts of water. Cane sugar is much sweeter than the other varieties. As much as 2½lbs of starch sugar would be required to equal in sweetening effect 1 lb. of cane sugar. Confining our attention, therefore, to the latter article, which is distinguished from the others by its crystalline character, we proceed to state some of its properties, and the mode of manufacture. In its pure form, as in loaf sugar, it consists of a collection of minute transparent crystals, which reflect and refract the rays of light within it so as to produce the effect of dazzling whiteness. When a lump of sugar is broken, it emits an electric spark, which is visible in the dark ; and when two pieces are rubbed together, a pale violet phosphorescent light is visible in the dark. The specific gravity of sugar is 1·6 ; it is soluble in about one-third of its weight of cold water, and in a much smaller quantity of boiling water. On evaporating the viscid syrup thus formed, fine crystals of *sugar candy* are deposited. A solution saturated at 230° (that is, sugar stirred in until the water will dissolve no more) forms in cooling a granular mass ; but when the solution is rapidly boiled down until it acquires a glass-like texture on cooling, it forms *barley sugar*, so called from its having been formerly made by rapidly boiling down a concentrated solution of sugar in barley water, heating the mass and cutting it while hot into strips, rolling the strips into cylinders, and then giving them a spiral twist. The candy does not long retain its vitreous and transparent appearance ; but it soon acquires a fibrous or granular texture, and becomes opaque. The show sticks in the windows of grocers are made of coloured glass, which resembles barley sugar in its freshest state.

The sugar-cane (*Saccharum officinarum*) is a perennial plant belonging to the family of the Grasses ; it varies in height from six to fifteen feet, and has a diameter of from one and a half to two inches ; it has a knotty stalk, and at each knot or stalk is a leaf and an inner joint: the number of joints may vary from forty to sixty, and even eighty in the Brazilian cane. The cultivator distinguishes three kinds of cane :—1, the *Creole* cane, with dark green leaves and a thin but very knotty stem ; 2, the *Batavian* or *striped* cane, with dense foliage, and covered with purple stripes ; and 3, the *Otaheite* cane, which grows luxuriantly, is the most juicy, and yields the largest product. It is chiefly cultivated in the West Indies and South America. The sugar-cane was originally a bog plant, and requires a moist nutritive soil and a hot tropical climate. It is propagated by slips, or pieces of the stem with buds on them; these are planted in holes from fifteen to eighteen inches square and from eight to twelve inches deep (fig. 576). It takes from twelve to sixteen months before the plant arrives at maturity. When the canes are ripe, they are cut, and the roots strike again and produce a fresh crop ; but in about six years they require to be removed and fresh ones planted : the canes which grow immediately from the planted slips are called *plant-canes*, while the sprouts from the old roots or stoles are named *rattoons*. The canes should be cut as close to the stole as possible, the juice of the lower joints being the richest ; the cane top, with one or two joints, is also cut off, when the canes are tied up in bundles (fig. 577) and sent to the crushing-mill (fig. 578). This consists of cast-iron rollers, worked by means of toothed wheels attached to the axles. The cane is crushed by the first pair of rollers, and the juice is expressed by the second pair ; the juice passes into a channel below, and then flows away to a reservoir. The crushed cane, called *cane-trash*, is used as fuel in the boiling-house, and the ashes are returned as manure to the cane plantation. The juice is clarified by means of heat, which coagulates the albumen, and by the addition of lime, which neutralizes the acid and renders some of the solid impurities insoluble. The old method of applying heat was by means of iron boilers, called *teaches* (fig. 579). The juice is conducted from the juice-reservoir, below the crushing mill, into the clarifying pan ; which is the largest, and situated farthest from the fire. The proper dose of milk of lime, or *temper*, as it is called, is added ; when a thick scum collects on the surface, and is removed by skimming. The juice is passed through four other teaches, and heated until the evaporation is complete, the scum being removed from each and passed into the molasses cistern, and is used for making rum. The scum consists of nearly pure sugar, decomposed by heat, together with the natural impurities of the juice. The syrup is known to be sufficiently concentrated in the last teach, when on taking up a small portion between the finger and thumb it can be drawn out into a thread of about half an inch in length. The syrup is then transferred to coolers or shallow open vessels (fig. 579), and in about twenty-four hours the sugar *grains*, that is, forms into a soft mass of crystals imbedded in molasses. The sugar in the coolers is frequently stirred with iron rods to equalize the temperature ; and it is then removed to the *curing-house*, and placed in hogsheads or *potting-casks*, which rest on an open framing over the molasses reservoir, a large cistern lined with lead. The bottom of each cask contains holes an inch in diameter, into each of which is thrust a plantain stalk extending to the top of the cask ; when, in the course of a few weeks, the molasses gradually drain away, leaving the crystalline portion of the sugar tolerably dry. There is a further drainage of molasses in the hold of the vessel after the casks have been shipped. Such is the *raw* sugar of commerce : it consists of a crystalline flour of pure sugar, moistened throughout with molasses, varying in quantity, but often containing one-third of its weight of that substance. Of late years, improved methods of evaporating the juice have been introduced, so that the system is not liable to the satirical remark which defined the old method as "an elaborate and effectual means of converting pure sugar into molasses and scum." The new system consists in the application of a regulated steam heat where heat is required ; separating solid matters from the juice by means of filters or flannel, or of animal charcoal ; and evaporating either by means of the *vacuum pan*, or in open pans containing a coil of steam pipe.

The manufacture of refined sugar in this country originated in the defective methods of preparing raw sugar in our colonies. It is still carried on to a large extent, in order to produce that beautiful variety of sugar known as *lump* or *loaf* sugar, which is probably used more or less in every house in the kingdom. The raw sugar from the West Indies, America, and the East Indies is imported in cases ; that from Jamaica, St. Domingo, and St. Croix in hogsheads ; from Manilla and the Mauritius in double sacks,

plaited or woven from the leaves of reeds; the man in fig. 580 is bringing in a sack of this kind. In the years 1857, 1858 and 1859, the quantity of unrefined sugar imported into the United Kingdom amounted to 7,346,933 cwts., 8,746,729 cwts. and 8,905,744 cwts. respectively: of refined sugar and candy during the same years, 298,948 cwts., 257,339 cwts. and 243,584 cwts. respectively. The following quantities of cane juice were also imported: 11,632 cwts., 57,361 cwts. and 17,028 cwts. respectively. Of molasses during the same years, 599,497 cwts., 819,226 cwts. and 680,763 cwts. respectively. The quality of *raw* sugar varies from white Havannah, which is almost equal to loaf sugar, to the dark brown, moist, sticky, and smeary characters of the worst varieties. The qualities recognised by our Custom House are, "first quality, equal to white clayed;" "second quality, not equal to white, but equal to brown clayed;" and "third quality, not equal to brown clayed." The term *clayed* refers to a process of partially refining the sugar by putting it in a mould and covering it with a thin paste of white clay, the water from which gradually drains through, driving the molasses before it, and thus gets rid of much colouring matter. But whatever the character of the sugar, the first operation of the refiner is to dissolve it in water. For this purpose the sugar is emptied on the floor (as in fig. 580), and the hogshead is inverted over an arched copper; while a jet of steam directed into it removes whatever sugar adheres to the staves. From the floor the sugar is shovelled into cisterns, named *blow-up cisterns* from the fact that a perforated steam pipe, fixed at the bottom of the pan, blows up steam through the water and completes the solution. The solution is clarified by stirring in a small portion of blood and ground animal charcoal, together with some lime-water for neutralizing the acid. The solution is stirred up with oars; and the albumen of the blood, dispersed through the solution, entangles and thus collects small mechanical impurities, and, coagulating by the heat, forms into large connected flocks, easily separable by strainers: it also forms with the charcoal a compact scum, which can be readily removed. Other mechanical impurities coated with albumen are separated by passing the solution through bags hung up in square vessels of iron, the top of which contains reservoirs for the concentrated solution obtained from the blow-up cisterns. In fig. 581 a portion of the iron case is removed to show the man engaged in fastening up the bags. The syrup, after it has run through the filters, is of a reddish colour, and is next passed through beds of animal charcoal, prepared by calcining bones in close vessels and reducing them to a coarse powder. The filters (fig. 582) consist of large vats twelve or fourteen feet in depth, with perforated false bottoms; these are covered with ticking, and the charcoal is then put in to the depth of twelve feet; above this is another layer of ticking, covered with a perforated metallic plate. The syrup is then poured over the surface, and by the time it has run through the filters, it has been deprived of colour by the curious attraction which exists between colouring matter and bone black. The syrup, now called *liquor*, is passed into the reservoir for supplying the boiler. The old method of concentrating the liquor to the point required for crystallization was by raising it in open vessels to the temperature of at least 230°; but at this point, and under the influence of the air, sugar quickly passes into molasses, or uncrystallizable sugar. By excluding the air, liquids will boil at a much lower temperature than when they are exposed to atmospheric pressure. Thus water, which boils under ordinary circumstances at 212°, will in vacuo boil at 90° or 100°; so also a solution of sugar which requires 230° under atmospheric pressure will, if that pressure be absent, boil at 150° or 160°. This is what is done in the vacuum pan (fig. 583); which consists of a large copper boiler of a spheroidal form, to enable it to resist the crushing pressure of the external air, which is equal to about fifteen pounds on every square inch of surface; and the pressure of the air from within is removed by means of a powerful air-pump: the lower half of the pan is double, for the purpose of admitting steam to heat the pan; and there is also a coil of steam pipes within the pan for assisting the evaporation. By continuing to work the air-pump, vapour of water which rises from the liquor is pumped out; so that the liquor can be kept boiling at a moderate steam heat. The attendant watches the progress of the concentration by means of a proof stick (fig. 586), which consists of a cylindrical rod, exactly fitting a hollow tube, which enters the pan in a slanting direction The upper end of the rod is open; but the lower end, which dips into the syrup, has a slit on one side of it about half an inch wide: within this tube is another shorter tube, which can be moved round in it through half a circle; near the lower end of this tube is a hollow, which corresponds with the slit in the outer tube. By making the slit and the cavity coincide, the latter is filled with sugar; and by turning the stick round through half a circle, the slit is covered by the fixed tube, and the inner tube can be withdrawn without allowing air to enter the pan. When it is ascertained, by drawing out a thread of the syrup between the finger and thumb, that the liquor will deposit its crystals on cooling, the air-pump is stopped, air is admitted into the pan to equalize the pressure, a plug at the bottom of the pan is opened, and the syrup flows into a *heater* in the room below. In this vessel, a portion of which is seen at the right of fig. 584, the syrup is raised to the temperature of 180° or 190°, twenty or thirty degrees higher than it was in the vacuum pan, in order to prevent crystallization before the sugar is placed in the moulds. To assist this object, men are employed in stirring up the syrup with poles. The conical sugar moulds are made of brown earthenware or of sheet iron; there is a hole in the pointed end which is first stopped with paper; and these moulds being set up, as shown in fig. 584, are filled from the heater by means of copper basins, and the sugar is stirred up in each mould in order to get rid of air bubbles, which would give the sugar a honeycombed appearance. The moulds are left in this condition for about twenty-four hours, and are then removed to an upper floor, where the temperature is maintained at about 80° by means of steam pipes; the paper plugs are taken out, and a wire is passed through the hole to insure an open channel, when the moulds are set in earthen jars or suspended in a framework over a gutter. The syrup which flows off is of a greenish colour, and this, with other syrups, are used for making a superior description of moist sugar. The sugar in the moulds is not yet of the proper colour: the crystals consist of pure sugar, with coloured syrup entangled among them. To remove this, a saturated solution of pure sugar is poured into each mould; being saturated, it cannot dissolve the crystals, but it washes them, and thus gets rid of the coloured syrup. The loaves improve in whiteness from the base to the point every time this operation is performed. They are removed from the moulds and are arranged in a hot room (fig. 585), which is kept at a constant temperature of about 140° by means of steam pipes. Shape is given to the loaves by passing them through a kind of lathe or a series of cutting blades arranged in a conical form (as in fig. 587), after which the loaves are tied up in paper and are ready for the market.

The syrups obtained in the above process are made granular by boiling, and are then transferred, in small portions at a time, to a *hydro-extractor* or perforated cylinder, which is made to revolve from 1200 to 1500 times a minute during a space of five minutes, the effect of which is to convert them into a clean, granular, sparkling light-coloured moist sugar. The syrups whirled out through the minute perforations of the cylinder are boiled down with other syrups and again passed through the machine: this process is known as the *centrifugal*.

The ordinary "scale" or grocery sugars of this country are known as *muscovado*, from the Portuguese word, *muscabado*, "more advanced;" that is, the West Indian and other American raw sugars are crystallized and cleared of molasses without being dried or decolourized.

Beet-root sugar is largely made on the Continent, and is imported into this country by the refiners. Sugar is made from the juice of the maple-tree in the United States of America. Of late years, the Chinese and African sugar-canes, known as the *Sorgho* and *Imphee*, belonging to the millets, have excited attention.

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INTRODUCTION.

In that very amusing book, Boswell's Life of Johnson, we read:—"I have often been astonished with what exactness and perspicuity he [Dr. Johnson] will explain the process of any art. He this morning explained to us all the operation of coining, and at night all the operation of brewing, so very clearly, that Mr. McQueen said, when he heard the first, he thought he had been bred in the Mint; when he heard the second, that he had been bred a brewer." And in another part Boswell says:—"It gives one much satisfaction to find such a man bestowing his attention on the useful arts of life."

This anecdote of a great and good man suggests to us a few thoughts which may serve as an appropriate introduction to a book on Trades. In the first place it must be noticed that Dr. Johnson's biographer, and the persons with whom the Doctor was conversing, were struck with the great extent and accuracy of his information on subjects which he, as a literary man, could scarcely be expected to be acquainted with. And this knowledge is the more remarkable, because at the time referred to, the Useful Arts had not been illuminated and made intelligible by the lamp of Science. It is, however, in the nature of a deep thinker to be a keen observer, and to know thoroughly and well whatever he professes to talk about. And in this respect Dr. Johnson's example may serve as a useful lesson to ourselves. If we cannot imitate his greatness, we can, at least, endeavour to imitate those habits of close observation and inquiry, which did not allow him to be satisfied with a thing until he thoroughly understood it.

We may observe in the second place, that the details of the Useful Arts, Trades, and Manufactures, may be naturally expected to possess a charm for deep thinkers and logical reasoners; since there is not a trade, however humble, that does not present to us a large amount of accumulated thought, the experience of many generations, if not of ages, as to the best methods of producing certain results, the best form of tool, the best mode of handling it, &c. In all these details, a high intelligence is visible *to* a high intelligence, mind claims affinity with mind, and delights in its exercise and application, although not on subjects peculiarly its own.

In the third place, a man of observation finds in the details of the Useful Arts large sources of prosperity to his country, and of peaceful and remunerative labour to his fellow-subjects. Dr. Johnson's definition of happiness was included in three words, "well directed employment;" and surely that employment is well directed, which supplies our ever-recurring wants, and makes men as dependent upon each other as they are upon the bounteous earth and sea, prepared by the Lord of all to fill "our hearts with food and gladness."

The mutual dependence of men upon each other in the production of the commonest article, is worth a little examination. Take so common an article as a needle. What a vast number of arrangements, what a wonderful complexity of interests are involved, before this little implement can be placed in the hands of the seamstress in its most efficient form; that is, not so hard as to break easily, not soft enough to bend, but perfectly smooth, sharp, with a well-formed eye that will not cut the thread, and opening into a groove which allows the thread to pass in readily. If we would write the history of a needle from the beginning, we must describe the magnificent forests of Sweden and Norway, where the miner is digging up a rich and pure iron ore, and the charcoal burner is felling the ancient trees and burning them into charcoal, so as to form a pure kind of fuel with which to smelt the rich ore, and so preserve the resulting metal from sulphur and other impurities which would deteriorate its quality. The metal, as it leaves the charcoal furnace, goes through sundry operations, and lastly appears in the form of bars of the best Swedish iron: these bars are stamped with peculiar marks, and are conveyed to the port of Oregrund (whence the iron is known in this country as *Oregrund iron*); there it is shipped and conveyed across the sea to the port of Hull, where merchants receive it and forward it to Sheffield for conversion into steel. At Sheffield it goes through a long process of cementation, ending in *blistered steel:* this is cast into ingots or tilted into bars, and passed on to the wire-drawer, who by a long and laborious process converts it into steel wire fit for the making of needles. Then, and not till then, does the needle-maker receive it in large thick coils: he cuts it up into lengths, equal to two needles each, straightens the wires, points the ends, forms the eyes, separates each length into two, rounds the heads, hardens and tempers the rough needles, submits them to a long and laborious course of polishing with oils and various polishing powders, drills the eyes, rubs up the points, sorts, examines, arranges and packs; and finally sends

them to the wholesale dealer, who distributes them to the shops and to the remotest corners of the habitable globe.

In this long detail what varied interests are brought into play! Men speaking another language, and with habits differing from our own, earn their daily bread in consequence of the demand for needles. Then what an amount of shipping is concerned, what a number of sailors, to say nothing of the ship-builders, the rope-makers, and the various subsidiary trades, any more than of the shops or fairs or markets where those poor Swedish workmen buy their necessaries of life, and let us hope some luxuries too; then again what an array of merchants and their clerks, porters and servants, what traffic on the railway, what numerous artisans engaged at Sheffield, and lastly what factories at Redditch, Feckenham, Bexley, and some other bright-looking Worcestershire villages with their neat cottages, all owing their prosperity to needles! But the history does not end here, for we must not only glance at the thousands of retail dealers, and the commerce of this little article, but we must also refer to circumstances calculated to touch our sympathy. There is something affecting in the thought that in the bazaars at Constantinople, Turkish women carry off packets of needles made in a Worcestershire village, which serve as the means whereby they earn their daily bread by embroidery work; while this in its turn is, perhaps, sent to England, to adorn the person of one of our fair daughters.

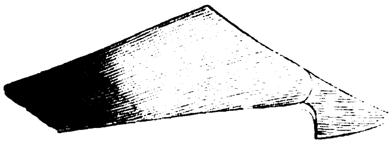
The following work is intended as a companion to the "Illustrations of Useful Arts and Manufactures." The broad distinction between a manufacture and a trade is, that the one performs its work by means of self-acting machines, the other by means of tools in the hands of a skilled workman. This definition, however, must not be insisted on too rigorously, for as the word manufacture literally means "made by hand" and practically something else, so many a trade which was formerly practised by single workmen has now become a manufacture, in which all, or most of its branches, are practised in one huge building, by hundreds of workpeople, often with the assistance of new or recently introduced machines. Of this, the bookbinder may be cited as an example. Bookbinding is strictly a trade in which there are many branches, all of which are exercised by skilled workpeople by the aid of a few simple tools. At the present day, however, a large London bookbinder's establishment resembles rather one of the great factories of Birmingham or Manchester than a tradesman's workshop; and a large amount of work, which was formerly done by hand, is now done partly by hand and partly by machinery, as in the *blind-tooling* and *gold-tooling* of books in which *block-presses* have been introduced.

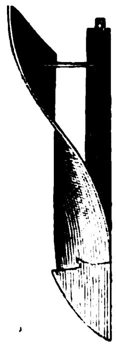
The Trades selected in these illustrations refer to the supply of Food, of Shelter, of Clothing, of Furniture, of Locomotion, and of Education. This is the author's arrangement of the wood-engravings placed at his disposal. These were originally made for a kind of Pictorial Vocabulary for the use of the Deaf and Dumb, in which the trades were arranged in alphabetical order. As the artists who made the drawings do not appear to have had much technological knowledge, they have not made their selections with judgment, but have often omitted a tool or machine peculiar to a trade, and frequently repeated the saws, gimlets, and planes which are common to most trades. The writer has endeavoured to supply these defects by introducing in many places new engravings; but the result is by no means so satisfactory as if he had had the supervision of the artists in the first place, instead of having to deal with their crude results. As it is, however, the reader will find a large amount of information respecting the commonest trades, obtainable at a very cheap rate, in consequence of the great bulk of the wood-engravings, which have already served, and are serving another purpose, being placed at the disposal of the Society for this work. The writer does not profess to give a complete book of trades, for he holds it to be useless to describe a trade, when he has not the means of sufficiently describing the object to be attained by that trade. For example, the Deaf and Dumb Vocabulary contains the tools used by the Watchmaker but not the working parts of the watch itself, which with the clock would require copious illustration. The writer has therefore preferred to omit such trades as could not be fully illustrated. Taking this work, however, in conjunction with the "Illustrations of Manufactures," the reader will find a large amount of information, collected both by the writer and the artist, on subjects in which we are all more or less personally interested.

KING'S COLLEGE, LONDON.

1860.

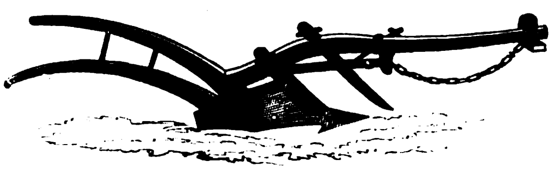
1. PLOUGHING.



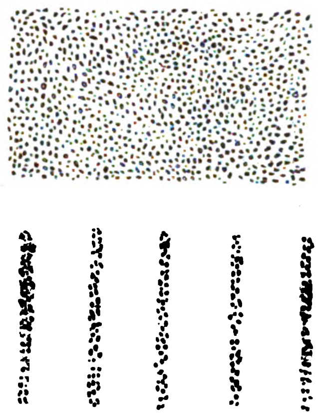


2. 3. MOULD-BOARD OR TURN-FURROW, *with the Share annexed.*

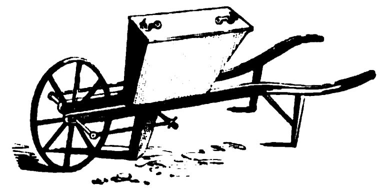
4. THE PLOUGH-FRAME.



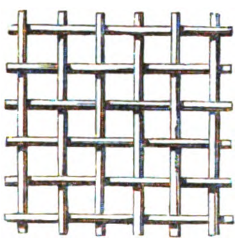
5. SMALL'S CHAIN PLOUGH.



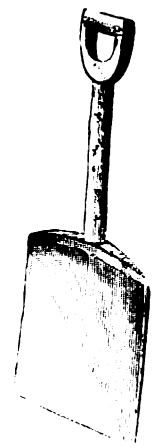
6. 7. SOWING BROADCAST AND BY DRILL.



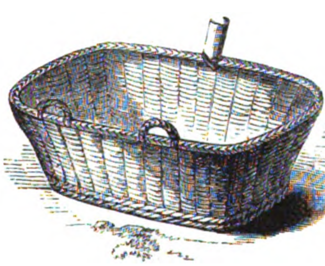
8. BEAN-DRILL.



9. REAL SIZE OF MESHES IN WHEAT RIDDLE.



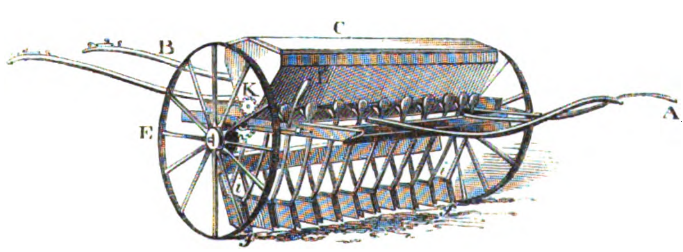
11. BARN-SHOVEL.



12. SEED-BASKET.

10. SOWING.

13. THE SHEPHERD'S MALLET.



14. DRILL-MACHINE.

15. DIBBLE.

I.—THE FARMER.

Agriculture cannot, strictly speaking, be called a trade, nor can it be rightly classed among manufactures, yet the farmer may be considered as the representative of a number of trades, by the exercise of which his labourers and servants earn their own living; while at the same time, he holds that kind of relationship to these labourers, which the manufacturer does to his workpeople, and lives upon the fruit of their toil in a similar way.

Taking the farmer, then, in the light of a representative of numerous trades, we proceed to notice the various operations and handicrafts carried on throughout the year in connexion with that diligent cultivation of the soil, that skilful gathering in and housing of produce, and that careful attention to live stock, which form the business, and contribute to the success of our agriculturists.

There is no time of the year at which the farmer can afford to be idle. Even "between hay-making and harvest," which is sometimes accounted his holiday time, or in "the dead of the year," when farming operations are checked by severe weather, there yet remains so much to be done, and the need of his personal supervision is so constantly required, that he finds it very difficult to get away from business on any errand of relaxation or pleasure.

Ploughing.—At all seasons of the year, but more especially in the spring and autumn, the ploughing of the land is a great and important work, and on its thorough and effective performance much of the success of the crops will necessarily depend. The best tools, the best workmen, and the farmer's eye, are all needed to insure a satisfactory result. The plough was originally a very simple implement: a stout limb of a tree, with a branch projecting from it, formed the rude means of turning up a light soil. The oxen were harnessed to the larger branch, while the smaller was shortened and pointed to serve as a ploughshare. Handles were afterwards added, and the ploughshare was shod with iron, in which form this peaceful implement was occasionally converted into a weapon of warfare; thus, "Beat your plowshares into swords," is a command given in the prophecy of Joel; happily counterbalanced by another prophecy of universal peace, when the nations of the earth shall "beat their swords into plowshares," and shall not learn war any more (Isa. ii. 4). The labour of the plough was comparatively light in the early period of the art (said to have originated in Egypt), for it was natural that when people were few and widely scattered, the spots easiest of tillage should be selected for cultivation; but as nations increased, and civilization extended, the less favourable lands were also brought into cultivation, and the implements were required to be better and more strongly constructed. At the present time, ploughs vary greatly in different parts of the earth, and betoken, to a great extent, the condition of the people in agricultural matters. In Bengal, a crooked piece of wood, sharpened at one end and shod with iron, is still used: to this two bullocks are attached, and the man or boy who guides the plough, pulls the animals this way or that by the tail. In some parts of Poland the plough is a wretched implement, constructed by the peasant himself, and scarcely doing more than scratch the surface of the land. The ploughs of Spain and of European Turkey are also rude and simple of construction. Our own plough was in early times as rude as theirs, and acted more as a clumsy rake for stirring the surface, than as a plough for turning over the soil. Yet our early agriculturists were wise enough to see that one plough would not suit all descriptions of soil, and as early as 1532 there were "divers sorts," according as the soil was light or heavy. But it was not until the middle of the eighteenth century that any very decided improvement was made in this implement. Much as the plough has been improved and modified since that time, yet it is to James Small, a Scottish farmer, that the honour is due of producing, about 1763, the first great improvement in ploughs, by making them much lighter and easier of draught than they had previously been. The plough known by his name (fig. 5) is still in very general use, and the essential parts of that, or of any other plough, are as follows. *The plough-frame* (fig. 4); this was formerly constructed of wood, but is now generally made of cast-iron, and is the part to which all the other parts of the plough are attached. The lower part of it is called the *sole*, and to the front part the *share* is attached, a keen blade of cast-iron, widening from the point, and cutting horizontally the slices of earth which are to be exposed to the action of the air. It is shown at figs. 2, 3, attached to the *mould-board*, a very important part of the plough, varying in shape according to the nature of the soil in which it is intended to be used, and made (notwithstanding its name) of cast-iron. Its use is to push aside and turn over the slice of earth just cut by the share, so as to leave a regular furrow. When the share and the mould-board are fastened to the frame, what is called the *plough-body* is complete, and when to this is attached at the fore part the *beam*, and at the hind part the *handles* or *stilts*, the plough is then fit for use, and has the appearance already referred to at fig. 5. The beam is about 3 feet long, and generally of wood: it has affixed to it in an upright position, a sharp cutting instrument called the *coulter*, the point of which nearly meets that of the share, and assists it in making a clean cut. At the extremity of the beam is the *plough-head*, a contrivance for regulating the depth of the plough and the line of draught. The stilts or handles extend backwards in the opposite direction from the beam, and are about 5½ feet long. They are wide enough apart for the ploughman to walk in the furrow as he raises, depresses, or turns the plough by holding these handles, and guiding them with the skill which experience teaches. The kind of plough represented at fig. 1 is called a *swing-plough*; but some are furnished with one or two wheels, and are called *wheel-ploughs*. Swing-ploughs are considered lightest of draught, but they require an experienced and attentive ploughman: wheel-ploughs work with greater steadiness, and require less skill in the guide. In the present rapid march of improvement in agricultural matters, there is every reason to believe that before many years shall have elapsed, this ancient occupation will, in some parts of the country, be taken out of the hands of our slow, but sure labourers, and will be accomplished by *steam-ploughs*, which will require a different mode of management.

Wheat-sowing.—Ploughing and harrowing are the preparatory steps to that great business of autumn and early winter, *wheat sowing*. In our illustration (fig. 10), that further harrowing which follows sowing is represented: it is a raking of the soil by means of a square frame of wood, furnished with a number of teeth, and drawn by horses, and it comes immediately after the sowing, because it will not do to leave the seed uncovered. Usually the sower has free scope for his work in a large open field, thoroughly prepared for the seed, and where the trees and hedgerows do not form an important feature. On the colder soils he commences his task in September or October, that the plants may obtain strength before winter sets in: on warm and rich soils he defers his task until November, lest the plants, by growing too rapidly, become what is called *winter-proud*, and thus yield in the following autumn a light crop.

The choice of seed is an important consideration, and can only be acquired by experience of the nature and requirements of the soil. And when the best seed has been selected, full, plump, sound, healthy, and free from the seeds of weeds, the preparatory

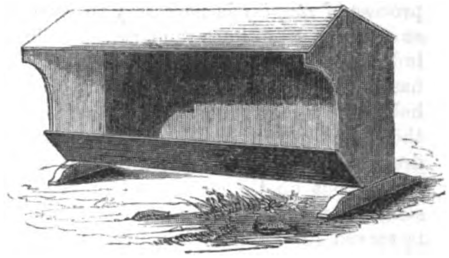
process of *steeping* is necessary to save it from a disease called *smut*, which sometimes renders a crop almost worthless. A basket holding about half a bushel is filled with corn, and lowered by handles into a tub of strong brine, or of chamber-ley, where it is held for two or three seconds, sometimes for several minutes, then lifted up and placed upon two sticks over an empty tub to drain, until another basketful is ready. The first basket is then poured out on the clean floor of the barn, and sprinkled with slaked caustic lime, from a wheat-riddle, another basket of wheat is served in the same manner, and so on: the whole heap of pickled and limed wheat is then repeatedly turned over by means of the barn-shovel (fig. 11), put into clean sacks, and carted at once to the field, only a sufficient quantity for one day's sowing being pickled at one time. If it is to be sown by hand or *broad-cast*, the sower fills a basket (fig. 12), slung across his shoulders, or it may be a box called the *seed lip*, of a similar shape, or it may be merely a large cloth, gathered into a kind of pocket or bag, and called the *sowing-sheet*. Keeping the hand low, taking up the seed firmly, and making short steps in advance, he casts forth the seed at every step, making it fly in a curve from right to left, and scattering it with an evenness and regularity which appears quite wonderful to inexperienced eyes. If the seed is to be sown by drill it is placed in the seed-box *C*, of a machine represented at fig. 14, within which seed-box, at its lower part, is a spindle or axle *K*, turned by the axle of the wheels. A series of grooved or fluted cylinders fixed to this axle, and revolving among the seeds, collect the wheat, and pass it in small regulated quantities through apertures in the bottom of the box, and into tubes or funnels, *i*, *i*, by which it is conveyed directly to the ground. Immediately before the lower part of each funnel, is a sharp hollow coulter of iron *f*, *f*, which forms the drill in each case just in time to receive the seed. By elevating the handles *A*, these tubes or funnels are lifted up when obstacles come in the way. This machine runs on large light wheels *E*, and is attached to the one or two horses which draw it by the shafts *B*. The two modes of sowing (broad-cast and by drill) are shown in figs. 6, 7. On certain light soils throughout England, a method of sowing called *dibbling* is practised. A light roller is passed over the prepared soil, after which a man, walking backwards with an iron dibble (fig. 15) in each hand, makes two rows of holes, and children following on his steps drop a few grains of corn into each hole, which is afterwards filled up by the passing of a roller or a bush-harrow over the soil. This mode of sowing is employed on light and sandy soils, and answers well in such situations.

Sowing, Weeding, Feeding Sheep, &c.—We have spoken of wheat-sowing as an autumn and early winter employment, but it is also carried on in the spring, when barley and oats, turnip-seed, mangold wurzel, beans, pease, &c. are also committed to the earth. Bean-sowing is in some places performed by dibbling, as above described, but oftener by a small machine called the *bean-drill* (fig. 8). A bean-field in blossom is one of the prettiest sights of the country, and the plants are often as nicely kept as a garden-crop, being carefully weeded with the *weed-hook* (fig. 37), in their early growth (fig. 19), and further protected afterwards by a double mould-board plough being driven between the ranks to throw the earth up in high ridges (fig. 26). Meanwhile numerous occupations are pressing on the farmer in this busy season of spring. Sheep-washing and sheep-shearing demand the care of those who cultivate flocks. In feeding sheep, a useful machine called a *turnip slicer* (fig. 20) is often carried to the field, and portions of the turnips in succession are pulled up, and cut in pieces for the sheep, who are apt to be wasteful when they help themselves. *Hay-racks* (fig. 25) are also generally provided for them, and these the shepherd fills afresh every day, opening the solid cover, which keeps the hay dry, and which also affords some little shelter to the sheep in wet weather, they being often found lying down on the side of the rack least exposed to the weather. In folding his sheep, the shepherd sometimes uses hurdles, sometimes nets: in the latter case, he drives in stakes at regular intervals by means of his *mallet* (fig. 13), and then attaches a netting of twine by means of a strong rope which passes through the top and bottom meshes, and which he secures to each stake by what is called the *shepherd's knot* (fig. 27). The food of the sheep consists, not only of hay and sliced turnips, but in time of need, of oil-cake, brewers' grains, potatoes, mangold wurzel, &c. For all such food, the *feeding-box* (fig. 18) is most useful.

Milking, Butter-making, Cheese-making.—Dairy-work is another important spring employment: the early dawn, and the early evening, find the farmer's boy engaged in driving home the cows (fig. 22), and soon the well-known operation of *milking* (fig. 17) is carried on. Regularity, gentleness, and cleanliness, are the requisite qualities in a milker; the same person, if possible, taking the same cows day by day, and milking them in the same order, while they are eating their fodder. The milk is carried to the dairy, a cool stone-paved room facing the north, and generally shaded by trees, and is there exposed in large shallow pans to a draught of air for twelve hours, in which time all the best of the cream has risen to the surface. This cream is skimmed off, and collected in a large jar for making butter. In dairies of the usual size, the cream is churned every two days. The common *upright churn* (fig. 24) is a wooden cask diminishing in size towards the top, and having a moveable round lid with a hole in the centre. Through this hole a stick passes, having at its lower end a round flat board with holes in it. By moving this stick up and down, slowly at first, and more rapidly afterwards, the cream in the churn is gradually converted into small lumps of butter, leaving a residue, called buttermilk, which is given to pigs. The lumps are collected and placed in a shallow tub, where they are worked into a mass with the hands or with a wooden beater, weighed up into pounds, and printed or rolled. The agitation of the cream which is necessary to produce butter, is often performed in what is called the *barrel churn* (fig. 30), which is a barrel turning on an axle by means of a common winch, and moved by the hand, by horse-power, or even by steam. But we have only accounted for the cream of the dairy, and it is now time to refer to the important uses of the milk. Milk, if left to become sour, separates into two parts, *curd*, and *whey*. Curd is the material for making cheese, but the product is not very agreeable from sour milk; therefore dairy-men have a method of curdling the milk without allowing it to become sour. But this is not done until a certain colour has been given to the milk, according to the sort of cheese to be made. The order of the work may be briefly stated thus: the milk in the cheese-tub is coloured by means of *annotta*, a hard reddish-yellow substance, obtained from the rind of the seeds of a South American plant (fig. 16). A little of this dye, which is tasteless and harmless, is dissolved in a small bowl of milk, making a deep coloured solution, and this is gradually mixed with the whole mass, which is then turned by means of rennet (a preparation from the gastric juice of the stomach of a calf) into curd. When the curd has fully formed, the dairy-maid breaks it up into fragments no larger than a hazel nut. This she does either with her hand and a small wooden dish, or with an instrument called a *curd-cutter* (fig. 23); she then presses in and piles up this curd in a small vat, the size and shape of the cheese to be made, on which she has previously spread a cheese-cloth, the ends of which she now turns over the top of the curd, and places the whole in a *cheese-press* (fig. 31), where it is subjected to considerable pressure, and where its superfluous whey runs off through holes which are purposely made in the bottom of the cheese-vat. In two days, during which the new cheese is taken out three or four times, wiped, turned, and replaced in the press, it is sufficiently solid to be placed in the salting tub, where it remains covered with brine for several days, and is afterwards taken out, and rubbed with salt daily for another week or ten days. It is then taken to the cheese-room, where repeated wipings, turnings, and airings, keep it from premature decay. The quality of cheese varies with the quality of the milk. This is ascertained by an instrument called the *lactometer* (fig. 35), which consists of graduated tubes, into

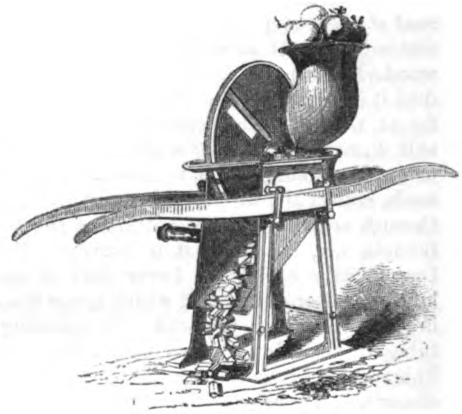
16. ANNOTTA PLANT. (*Bixa Orellana.*)

17. MILKING.

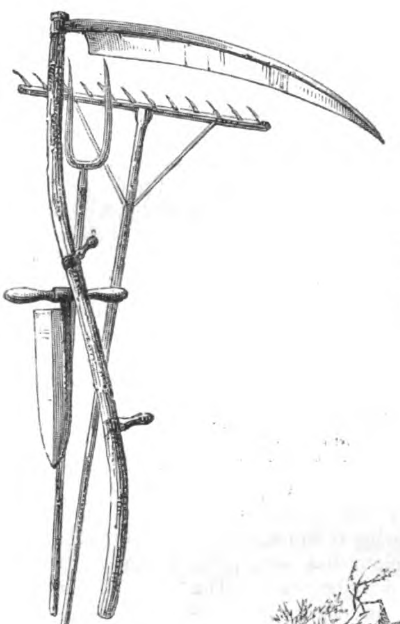


18. FEEDING-BOX.

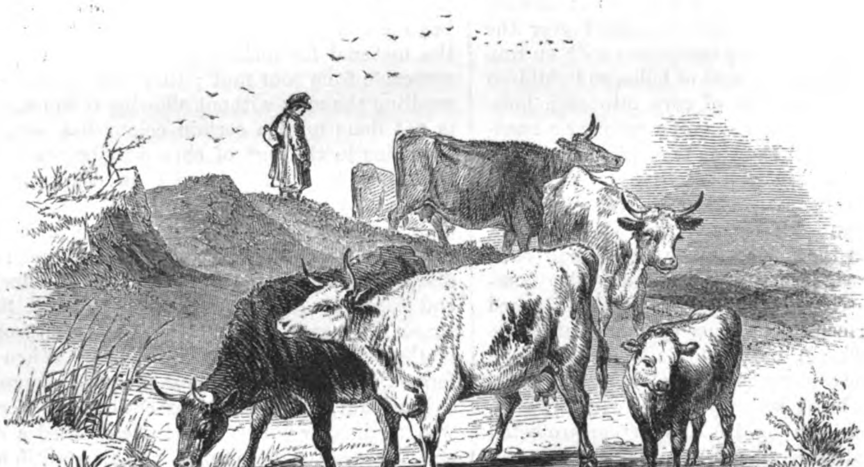
19. HOEING TURNIPS.



20. TURNIP-SLICER.

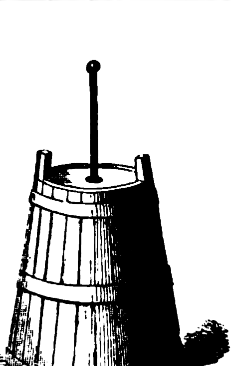


21. HAY-MAKING IMPLEMENTS.

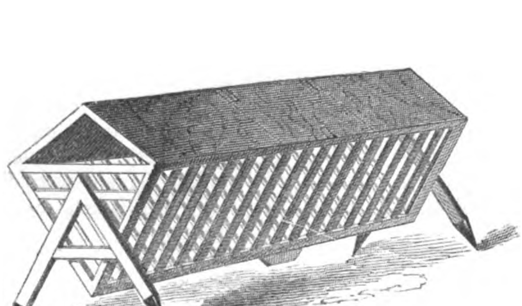


22. FETCHING HOME THE COWS.

23. THE CURD-CUTTER.

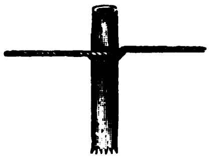


24. UPRIGHT CHURN.

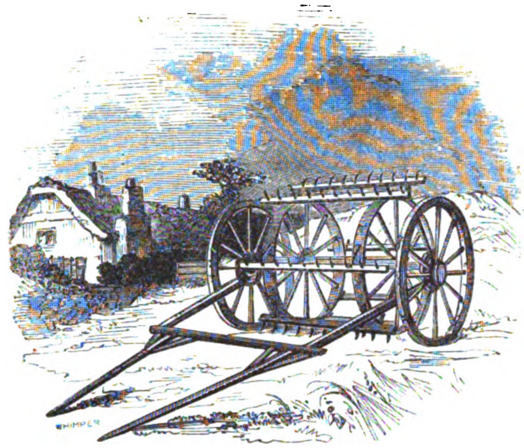


25. HAY-RACK.

26. BEANS CULTIVATED ON RIDGES.

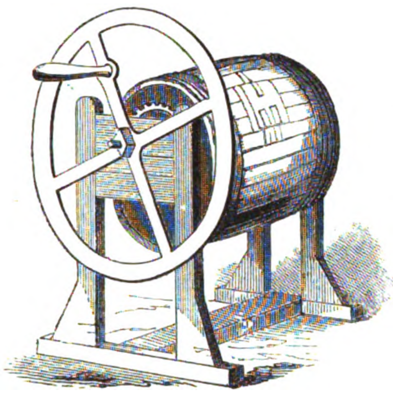


27 THE SHEPHERD'S KNOT.

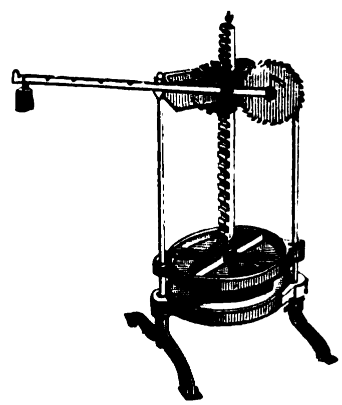


28. HAY-TEDDING MACHINE.

29. WINDLE, OR TURNER.



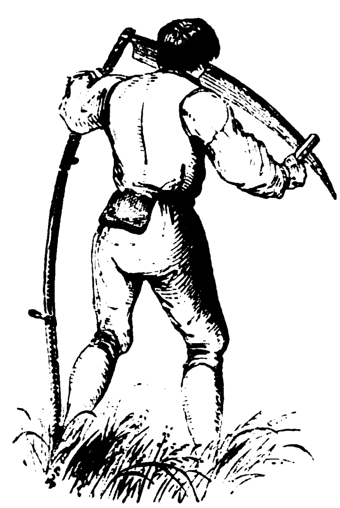
30. BARREL-CHURN.



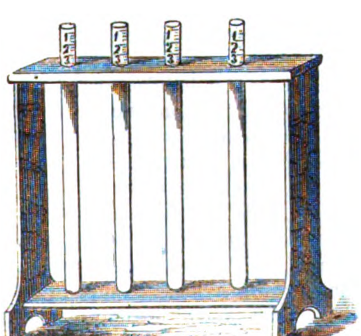
31. IMPROVED CHEESE-PRESS.

32. MOWING.

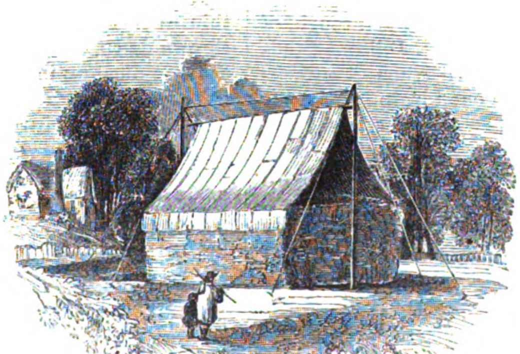
33. LOADING HAY.



34. WHETTING THE SCYTHE.



35. THE LACTOMETER.



36. THE RICK-CLOTH.

37. THE WEED-HOOK.

which the milk of different cows is poured, and by the amount of cream which settles at the top of each tube, the richness of the respective milks is ascertained.

Hay-making.—Spring advances, and soon these blooming pastures must yield their fragrant and nourishing grasses to the *mower's scythe* (fig. 34), for no sooner have the fields and hedgerows attained their utmost beauty, than hay-making begins, and hundreds of wild flowers fall at every sweep of the *mower's* arm (fig. 32). The spreading and tossing of the grass, until it has dried into hay, is usually the pleasant task of men and women with long rakes, who finally gather it into haycocks, and help to *load* the wagon (fig. 33), which bears it to the rick-yard; but in the neighbourhood of large towns, the process is hastened by the use of the *hay-tedding machine* (fig. 28), which is drawn by one horse, and which catches up and tosses about the new hay in a constant whirl. The variable nature of our climate at the hay-making seasons, makes this a very precarious crop, and when put together in a damp condition, the hay sometimes ferments to such a degree as to take fire. Care is therefore necessary not only to collect the hay in a dry state, but to keep the rick dry while making. This is now facilitated by the *rick-cloth* (fig. 36), a useful article, suspended by means of poles and cords over the rick, and forming a roof to it, while it is being made. Haymakers find many a use for a rope of hay twisted on itself, and called a *hay-band.* This is made by means of a little instrument called a *windle* or *twiner,* (fig. 29); the hay is damped, and is readily twined into a tolerably strong rope, which serves to tie up the hay in trusses, &c. The *mower's scythe,* the *prong,* the *rake,* and the *hay-knife,* form the group of hay-making implements at fig. 21.

Wheat-harvest.—All through the hay-making season, the farmer's watchful eye has been frequently turned on another crop, the most important of the whole year, now approaching perfection. The term harvest applies to the gathering in of all the crops, whether of wheat, barley, oats, or of pease, beans, &c. But we can only now speak of the *wheat-harvest,* the grand object of attention to the farmer, during which he postpones as far as possible all other business and pleasure, and devotes himself, heart and hand, to his work. The number of insect enemies which beset the wheat-crop is so great, that it seems wonderful how any crop can reach perfection. Notwithstanding all precautions of steeping, liming, &c., the grain is no sooner committed to the earth and beginning to vegetate, than it is attacked by a caterpillar (that of the *Wheat Dart Moth*), which feeds on the young root. In the spring another enemy appears in the *Wheat Stem Fly* (fig. 41), which lays its eggs in the very core of the young plant, entirely destroying the primary shoot. Such is the vigour and activity of the root, however, that a dozen new stems and ears are sometimes sent up to repair the mischief, and thus the apparent enemy becomes a friend. Later in the season, the *Wheat Midge* (fig. 40) deposits its eggs in the blossom, the young larvæ feeding on the pollen, and causing the grain to shrivel and decay. These larvæ are in their turn attacked by a small black fly called an *ichneumon,* which inserts her eggs beneath their skin, and these, when hatched, feed on the caterpillars to their destruction. While these evils are going on above ground, the *Wire-worm* and the *Slug* are at work below. The wire-worm is the grub of an insect called (from a peculiar sound which it makes) the *click beetle.* The worm is long and tough, of a deep yellow, except the head, which is brown. Diligent hand-picking is of some use in checking this evil when it attacks turnips, fifty worms having been found in one turnip. In wheat-fields slices of potato fixed on skewers are sometimes buried and pulled up at intervals, and the worms removed. At other times the land is watered with a saline solution, or it is left fallow until the enemy is starved out. Another evil to the wheat-crop is called *ear-cockle, purples,* or *pepper-corn.* The grain becomes nearly black, and rounded like a pepper-corn. It is full of a cottony looking substance, which under the microscope proves to be a multitude of writhing active creatures like snakes. This is one of the most serious of the many forms of *blight,* consisting of that vast development of microscopic insects, or of parasitic fungi, which forms so wonderful a field for inquiry and observation.

Reaping.—But supposing the crop to have arrived at healthy maturity, the glad preparations for harvest are made, and soon the fields present a lively scene, with reapers bending amidst the corn (fig. 46), and masters riding from place to place to superintend their labours. The ordinary implement for reaping is the *sickle,* a simple hook of iron, edged with steel, which does its work well and with little waste when it is in good hands. A good reaper crouches down on his right leg, and extending the left to steady himself, seizes small portions of corn with his left hand, and with his right draws the sickle across their stems, as near to and parallel with the ground as possible, pulling it towards him as he does so. Without changing his position, he makes a sort of creeping movement towards the left, and cuts another portion, laying the corn in handfuls within a band made of corn-stalks, which is used to bind up the sheaf, a task performed by another person who follows the reaper. Corn is now very frequently reaped with the scythe instead of the sickle, which is a more expeditious process, but gives more trouble in setting the wheat up in stacks. Where the scythe is adopted, strong and able workmen are required, the task being one of the hardest known in agriculture. The nature of his implement prevents the scythe-reaper from laying the corn evenly on the bands, therefore another labourer follows for that purpose; a third binds the sheaves, and a fourth clears the ground with a rake. When the bandster has made a sufficient number of sheaves, he sets them up in a stack or shock. He takes two sheaves, one in each hand, sets them a little way apart on the ground, and brings their heads together. He then sets up others, until a double row of sheaves, seven in length, is set up, each pair supporting itself and not leaning against the others, although close to them. Barley and oats are frequently *hooded,* that is, covered in by inverted sheaves, but wheat is seldom protected in this manner. Small sheaves are preferred to large ones; they are sooner dried, and less liable to damage. If the wheat be secured in really good condition the grain will be plump, smooth, and of a bright colour.

Loading, Stacking, Threshing, Storing, &c.—When dry and fit for carrying, the sheaves are loaded and taken home to form stacks. These have a raised platform of wood or iron, on which the sheaves are cleverly built up with the grain inwards, and are secured at the top by a covering of thatch. Here they are safe, and form stacks which as they multiply in the rick-yard afford goodly evidence of the abundance of the harvest and of the wealth of the farmer, each rick being of the average value of about £100. In this state the ricks may remain for months or years, as it may suit the pleasure or convenience of their owner; but when the time comes for taking in the rick, and for threshing and selling, or stowing the grain, the proceedings are as follows:—The work of taking in a rick (fig. 39) occupies a few labourers, and a superintendent; the latter mounts the rick and cuts away the tyings of the straw ropes at the eaves, preparatory to removing with a small pitchfork the whole covering of the rick, and throwing it on the ground. The labourers spread out a layer of this straw on the ground on the side of the rick nearest the barn, and spread the barn-sheet upon it, drawing the latter close to the rick. This is a large piece of thin canvas about 12 feet square, and upon this the sheaves are thrown down, and thence conveyed in barrows to the barn where they are piled up in rows to a considerable height with their butt ends outwards. In this way the whole rick is taken in, and the loose corn in the barn-sheet is also emptied on the barn-floor. If possible a dry day is selected for the work, and a stack thus housed may remain in the barn without injury until a wet day deprives the labourers of out-door employments, and makes it convenient to resort to the *flail.* This is a simple implement, but it requires a great expenditure of time and labour, hence the farmer often resorts to machinery. The flail consists of two rods of ash of unequal length, connected by a loose swing joint of leather; the longer rod, called the *helve,* is held in the workman's

hands, while the shorter rod or *beater* is applied to the threshing out of the corn. The skill of the work consists in making every part of the beater strike the floor with equal force, and have its full effect on the opened sheaves, hence the peculiar dull flat sound of the flail, which is heard hour after hour with little variation in some farm-yards. But more frequently a sound, louder and more shrill, announces that machinery is at work, and on looking into the rick-yard, the threshing-machine (fig. 45) is seen in full action with a horse attached to each of the projecting beams, and a boy seated in the centre holding in his hand a long whip, with which he keeps up the speed of the poor animals condemned to this giddy round of labour. The action of the machine on the wheat will be understood by reference to fig. 49, which shows the working parts. At *A* are fluted iron rollers between which the unthreshed corn passes, straw, ears, and grain. Thence it is carried over a cylinder or drum *B*, containing four projections or beaters which revolve rapidly. It next reaches a second cylinder where it is acted upon by four rakes, and where the grain and chaff fall down into a winnowing-machine below, and the straw is carried on to another cylinder *D*, where it is again shaken by rakes before it is thrown out at the end of the machine. Sometimes there are brushes affixed to the last cylinder in order to sweep back any corn or chaff which may have fallen into the cavity at *E*. Whether the corn be threshed by flail or machine, the next operation is *winnowing*. The *winnowing-machine* (fig. 50) is simple in its construction. Four or more boards are fixed at equal distances from each other on an axle, extending through the machine, and whirled round by a wheel acting on a pinion. A current of air is thus produced within the machine, and the corn which is put into a hopper at the top, falls gradually through this current, and the chaff is blown out at the tail of the machine while the heavy grain falls down and is collected beneath. The corn thus winnowed is next riddled, in order to separate earth, stones, &c. Sieves or riddles of different degrees of fineness are used (figs. 43, 44), but the meshes must always be rather coarse, to allow the grain to pass through; the usual size is shown at fig. 9. Corn is measured out by the *Imperial bushel*, fig. 48; this is 8 inches deep, and rather more than 18½ inches across, and contains 2,815 cubic inches. The grain is swept off on a level with the rim of the bushel by a flat piece of wood, called a *strike*, fig. 42. Three of these bushels make one *sack;* in moving the sacks of wheat from place to place the *sack-barrow* (fig. 38) is indispensable. In former years, wheat was largely stored in granaries, as is still the custom on some parts of the continent, though it has fallen into comparative disuse in this country.

Where this custom still prevails the proceedings are as follows:—The granary, which is generally in some high and dry situation, receives the corn by degrees. It occupies the floor in heaps, spaces being left between them, both for ventilation and for the convenience of the labourers who at stated intervals turn and toss the grain with their barn-shovels. At first only about six inches in depth of corn is placed on the barn-floor, and this is completely turned at least twice a week. A month later, another six inches of corn is added, and the whole is turned once a week. After six months have elapsed, the heaps are raised to two feet in thickness, and are turned about once a fortnight, so the corn is gradually raised, and the turnings become fewer as the mass becomes less manageable; but however long the wheat may remain in the granary, it is improved by frequent turnings, and by passing through screens or large sieve-like frames. Granaries have more than one story (public granaries have seven, eight, or nine stories), and in some cases there are large square or circular holes in the floor through which the corn is tossed from the upper to the lower room. Where corn is properly turned, screened, and ventilated, it will keep in one climate thirty years. In Switzerland corn has been kept 80 years by the same means. In Russia, corn is preserved in subterranean granaries wide below and narrow above, and the wheat is kiln-dried while in the sheaf, because the summers are too short to allow of its being properly dried in the field.

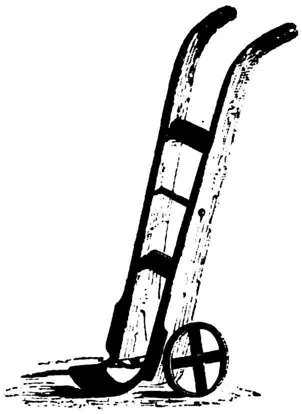
Every part of the wheat plant is useful; even the chaff or husk of the grain is in some places mixed with corn and given to cattle. Wheat-straw has many and important uses in the manufacture of hats and bonnets, of baskets, boxes, mattrasses, bee-hives, &c.; it also forms the best kind of thatch. It forms also a considerable part of the provender of live stock, and for this purpose is cut into short lengths by a machine called a *chaff-cutter* (fig. 47), and the straw when thus mixed up is called *chaff*, being divided into portions as small as the real chaff or husk of the grain.

Cider-making.—When the main business of the harvest is over, a time of comparative leisure gives opportunity for the ingatherings of the orchard and garden. In some parts of England, especially in the cider districts of Hereford and Devon, the gathering in of apples and the making of cider becomes a general employment, occupying a large number of hands; in other parts of the country, where the orchards are comparatively small, it is yet very common to see the cider-press at work, or on its road from one village to another, as it is let out on hire to different persons in succession. Cider-orchards began to be planted in Herefordshire in the reign of Charles I., and the first cider made in England was esteemed as highly as foreign wine, and was expected to supersede its use. And in fact, at the present day, the best and sweetest cider forms the staple of many wines sold as foreign.

If we trace the cultivation of the apple from the commencement, we find the first step to be, the preparation of a soil of good quality as a nursery ground, and the planting therein a number of young seedlings of the crab, six feet apart. The following year they will be fit for *grafting*, that curious and interesting art by which the shoot of a tree bearing large and delicious fruit is incorporated with the hardier stock of an inferior tree of the same species, and becomes a flourishing tree, bearing, not the sour fruit of the stock, but the rich fruit of the scion. In its wild state the apple is nothing more than the sour crab of our hedges; in its domesticated state it seems capable of almost endless improvement.

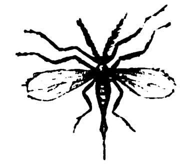
Grafting.—There are several different kinds of grafting, named according to the form of the graft and the mode of insertion:—thus, in *saddle-grafting* (fig. 51), the stock is cut in the form of a wedge, and the graft is shaped so as to fit over it like a saddle; in *whip*, or *tongue grafting* (fig. 52), the stock is cut through in a slanting manner, and the scion is cut into a long tongue, which fits the stock and is its exact counterpart; in *crown-grafting* (fig. 53) (only performed on large stems or limbs with thick bark), the limb is sawn through horizontally, a piece of flat wood or ivory is then slipped between the bark and wood so as to make a small cleft or opening in the crown of the stock, and into this the graft is inserted. In *cleft-grafting* (fig. 54), the stock is also sawn through horizontally, and cleft deeply, the cleft being kept open with a chisel until the graft is inserted, when it closes firmly on it.

Whatever may be the form of the graft, it is bound and secured with strips of matting, and further protected with grafting-clay, or some other composition, pressed round the stem so as to exclude the air, until the union of the scion and the stock be complete. Grafting is performed at two years old; but it will be five or six years longer before the trees will come to their full bearing. The young trees are transplanted from the nursery to the orchard before their branches begin to interfere with one another. The month of October or November is the best time for this work, when, if carefully removed, the trees will send out a few rootlets before winter, and will make a vigorous growth in the spring. Most of their side branches are taken off previous to removal, but the roots are carefully preserved, and placed in a hole deeper than that from which they were taken, and wide enough to allow of their being spread out in a natural manner, before the soil and turf is covered in upon them. Each transplanted tree requires for the first year a stake and a few bushes to protect it. A straight stem six feet high,



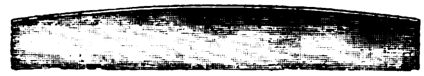
38. SACK BARROW.

39. THE FLAIL.

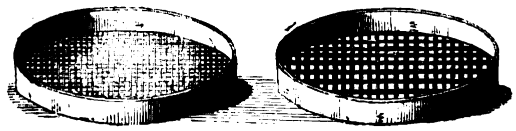


40. WHEAT-MIDGE. *Magnified.*

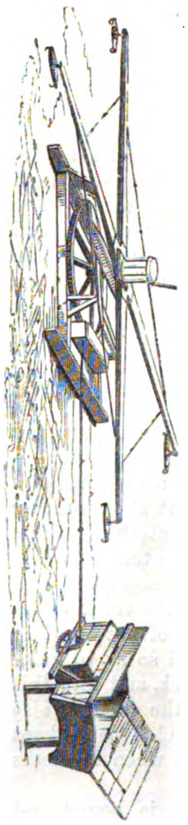
41. WHEAT-STEM-FLY. *Magnified.*



42. THE STRIKE.



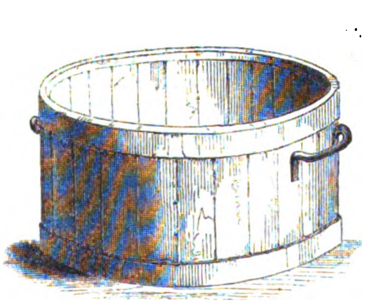
43. 44. CORN RIDDLES.



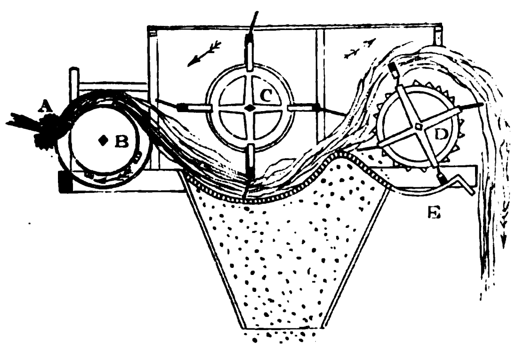
45. THRESHING-MACHINE.

46. REAPING.

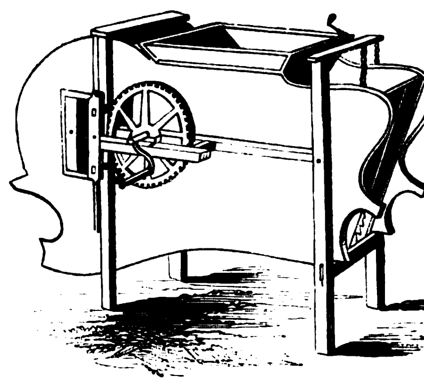
47. CHAFF-CUTTING.



48. IMPERIAL BUSHEL.



49. WORKING PARTS OF THRESHING-MACHINES.



50. WINNOWING-MACHINE.

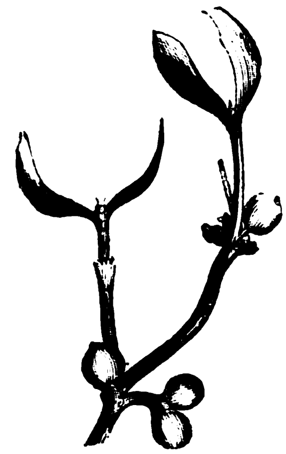
51. SADDLE GRAFTING.

52. TONGUE GRAFTING.

53. CROWN GRAFTING.

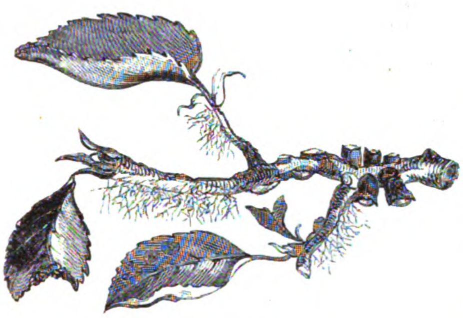
54. CLEFT GRAFTING.

55.



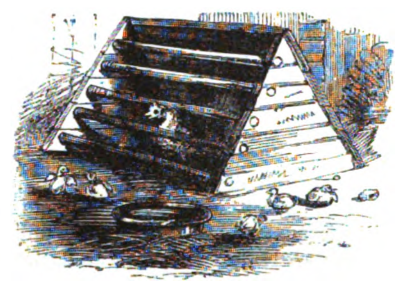
56. COMMON MISLETOE.

57. AMERICAN BLIGHT. (*Magnified.*)



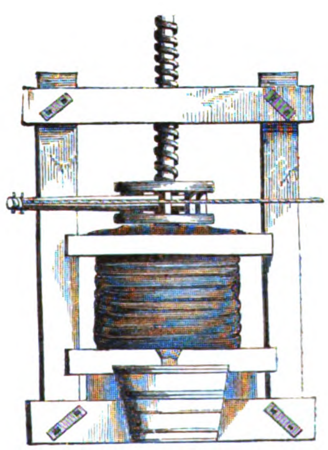
58. BLIGHTED BRANCH.

59. GATHERING APPLES.

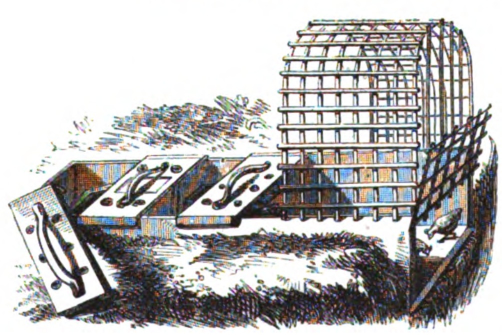


60. HEN COOP

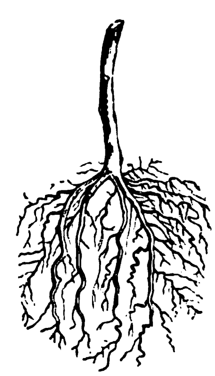
61. BROOD BASKET.



62. CIDER PRESS.



63. ARTIFICIAL MOTHER. (*Improved form.*)



64. THORN-PLANT PREPARED FOR PLANTING.

and three or four healthy shoots to form a head, are the requisites for one of these orchard trees or *standards.* A smaller tree dwarfed by judicious pruning is grown in gardens and called a *dwarf.* This is more generally adopted in the present day than the old form of training apple-trees on a frame, when they were called *espaliers.* But there is many an old-fashioned garden in which these espaliers still form the tempting fruit-wall which divides the flower-beds from the vegetables. Young trees of too luxuriant growth, whether espaliers or standards, must be checked by judicious pruning, but this process is best performed in the youth of the tree, and is apt, unless great caution is observed, to do serious injury to the old trees.

The orchard is liable to the inroads of various enemies, one of the most formidable of which is called American blight (*Eriosoma mali*). It is a small wingless insect (fig. 57), which preys on the bark and forms from its body a covering of down or cotton under which it carries on its work. It pierces the bark by means of a beak terminating in a fine bristle, which penetrates to the sap and extracts it as with a syringe. The sap-wood thus wounded, rises in knots all along the branch, and these with the cottony appearance, are tokens too well known to the gardener that his trees are infected with multitudes of this kind of blight (fig. 58). The only remedy is to clean every part of the bark with a hard brush and some searching wash, or, when the blight has penetrated too deeply to be removed with a brush, to varnish the branches with a mixture of resin and fish oil, which hardens on the tree and stifles the insects. Another great enemy to orchards is the Common Misletoe (*Viscum album* fig. 56), a parasitic plant, which fixes on the bark and lives at its expense. The seed being deposited by birds, a little rootlet issues forth, and takes fast hold of the bark, finally reaching the soft wood and obtaining all its nourishment from the sap. When two or three plants infest one branch, the latter withers away and dies, the parasites dying with it. To diminish this evil (which in the cider districts prevails to an extent scarcely dreamed of elsewhere) a labourer is sent among the trees in frosty weather when the misletoe is brittle, to pull off the plants with a hook, thus clearing fifty or sixty trees in a day.

When the crop of the cider-orchards is ready to be gathered in, the trees are generally beaten with poles (this is called *poulting*), and the whole of the apples are thus obtained at once; but a better plan is to send men into the trees, either to gather or to shake down such apples as are ripe (fig. 59), leaving the remainder for a subsequent operation. This gives more trouble, and is therefore the less general plan; but it saves the young wood of the tree from the injuries inflicted by the poles. The cider is also improved by allowing all the apples to be equally ripe before the operation commences. The fruit should be kept till it is perfectly mellow. To hasten this process, it is usually placed in heaps of about a foot in thickness, and exposed to the sun, air, and rain. The experience of the cider-maker enables him to judge when the apples are in the best state for his purpose, and he then causes them to be ground in a horse-mill, or a hand-mill, according to the quantity to be made. The hand-mill (fig. 55) consists of a pair of toothed wooden rollers, or preferably, a pair of fluted iron ones, with a feeder at the top and a handle at the side. The cylinders can be so adjusted as to reduce the pulp by degrees, so that at last scarcely a pip can pass unbruised. The pulp is called "must," and the juice is pressed out of it in the following manner. A large horsehair cloth is spread out on the cider press (fig. 62), and some of the must poured into it from a pail. The ends of the cloth are then folded over, and another is laid upon it, and filled with must in a similar manner. Ten or twelve hair-cloths are thus filled, and the ends neatly turned inwards, after which a heavy wooden frame is placed on the top, and the screw slowly brought down upon it by means of a lever. A thick juice soon begins to pour out on all sides from the hair-cloths, and, after a time, nothing is left but dry must. This is sometimes ground up again with water, and the liquid pressed out of it as before. This forms the weak beverage called "water-cider," which is drunk early in the year. In the Devonshire cider-press, reed, or unthreshed straw, is used instead of hair-cloth. The cider is at once put into casks, where, in three or four days, it will begin to ferment; the thicker parts of the liquor subsiding to the bottom, and the lighter becoming bright and clear. The bright portion is then drawn off into other casks, and this has to be repeated again and again, if active fermentation continue. Much trouble and difficulty occasionally attend the making of fine cider; hence the beverage is less common than, on account of its excellence, it deserves to be.

The Poultry Yard.—Although the rearing of poultry is an occupation chiefly carried on in the Spring, yet the care of fowls is a business of the whole year, and we may briefly allude to it here as one of the common operations of the farm. The Hen Coop (fig. 60) and its pretty little chirping brood forms one of the prettiest sights of spring, and is the great delight of childhood. The old, rough form of hen coop still exists, where the imprisoned hen vainly calls her wandering and scattered family; and where it would seem an especial cruelty to shut her up, did we not know that, in her zeal to find food for her offspring, she would infallibly lead them, were she at liberty, to distant and dangerous spots, where their lives would fall a sacrifice to some of their many enemies. For the fox, the weasel, the rat, and the pole-cat, are as fond of young chickens as any human epicure can be, and several of the young brood often fall victims to their rapacity, notwithstanding all the care which may be taken of them. When chickens first leave the shell, they require great attention, not only daily, but almost hourly. Food should be taken to them fresh every three hours during daylight, and water, in a very shallow dish, should be even more frequently renewed. Bread crumbs, finely crumbled boiled potato, groats, rice, and pearl barley, may be given in turn, in small quantities, and fresh every time. This done, and due precautions observed to keep them warm, clean, dry, and safe from their enemies, the chickens will generally be healthy, and will grow rapidly, becoming daily more able to provide for their own wants, and to forage for provisions in the neighbourhood of the crops. In Scotland, a hen and her chickens are sometimes carried out to the turnip-field, that the latter may pick up the larvæ which are so destructive to young turnip plants. For this purpose, a Brood basket (fig. 61) is used. A large woollen cover keeps the chickens from escaping between the bars during the removal; but when this is taken off, they issue forth, leaving their mother, as usual, a prisoner. When they have exhausted the insects in one patch of turnips, the brood-basket is moved on to a new spot, the chickens following and proceeding with their task.

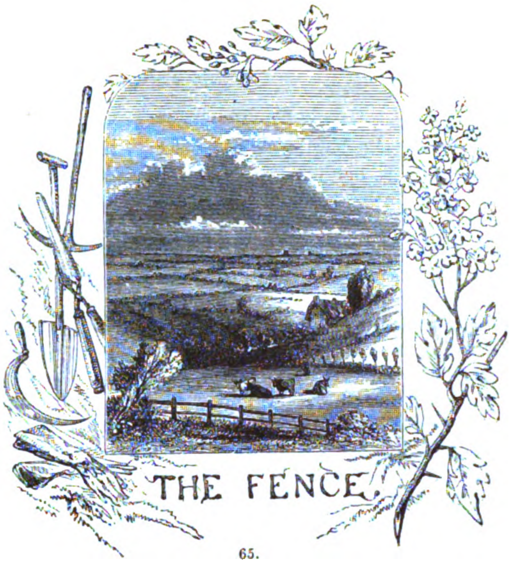
The difficulty of rearing a sufficient quantity of chickens in the natural way, led to the hatching of eggs by artificial heat, supplied by steam or dung, and the naturalist, Réaumur, invented what he called an Artificial Mother (fig. 63), in order to supply, as far as possible, the warmth and protection afforded by the hen. Boxes with sloping covers, lined with sheep-skin, the wool inwards, allowed of the chickens arranging themselves according to their size: the ends of the boxes were open to prevent suffocation. The boxes were placed at the end of a little feeding ground, the top of which was covered in by willow or wire. Several other forms were also employed, but none of these attempts to substitute artificial for natural heat, appear to have been permanently successful. This contrivance was intended by its inventor to be useful for turkeys, pheasants, and other birds that do not go into the water.

In a large farm, the management of the poultry-yard is generally assigned to one person, and its duties may well be performed by a cleanly, good-tempered woman. The hen-house and hatching-house should be guarded from all other visits except those of this woman, whose familiar voice will not disturb the fowls. The hours for feeding poultry should be strictly observed, for they will never fatten or thrive properly with uncertain, irregular meals. Even what are called "barn-door fowls," which

are supposed to pick up plenty of grain, are improved by a daily small meal, regularly given. The knowledge of the various kinds of food, which best suit the health of the different descriptions of poultry, and some acquaintance with the diseases common among them, are necessary qualifications in those who have the care of them. The vegetable diet of poultry is most extensive; but the principal dependence will always be on barley, wheat, and oats, the inferior samples of which are laid aside for the purpose. It is a pretty sight to witness the daily feeding of the birds. At the well-known call of their mistress, they come running and flying from every part of the premises with eager cluckings and cries, and great rustling of feathers (fig. 79). There assemble the lordly peacock, the stately turkey, the clamorous goose and duck, the pigeon, the ordinary fowl, and the guinea fowl. Outside all, or even boldly pushing in among them, are sparrows and other small birds eager to share in the booty. The value of fowls and their eggs, and the ready sale for them in all our great towns, make it a matter of surprise that these birds are not more cultivated by the humble classes in the country. Their tendency to scratch and tear up gardens may be one reason for the small estimation in which they are held; but it has been said, that every cottager who keeps a pig should also keep fowls; their summer food being sufficiently provided for by a few potatoes and peelings, and the run of the pig's trough, and the winter supply being only a little oats, barley-meal, or Indian corn.

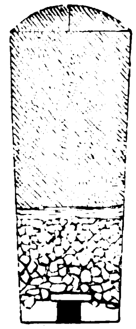
Hedging and Ditching.—Among winter employments which fill up any little leisure which may fall to the lot of the farmer, is that of looking to the fences. These form a great part of the beauty of an English landscape, and give the garden-like appearance which is so attractive to foreigners. On looking over a considerable tract of country, especially in the southern parts of the kingdom, the divisions of the fields, instead of being formal barriers of wood or stone, are undulating lines of living verdure, whose rich dark green forms a beautiful contrast with the ripening crops, or a harmonious border to the tender green of the pastures (fig. 65). This fence almost universally consists of the common hawthorn (*Cratægus oxycantha*), which is the *aubépine* of the French, and the *hagedorn* of the Germans, and which is too well known to need description, forming the "May" of our spring season, and the "haws" or red berries of autumn. Hawthorn plants are raised from seed in nurseries; but they do not germinate till the second spring, and it takes five or six years to rear plants which shall be useful in hedgerows. A quicker way is to plant fragments or trimmings of the roots of older plants. These, if buried deep in rich earth, beyond the influence of frost, will sprout in the following spring, and grow quickly afterwards. A hawthorn fence is usually formed by the union of hedge and ditch, for which purpose a ditch is prepared by means of the ditcher's shovel (fig. 77), and the earth thus thrown up forms a mound, on the slope of which the hedge is planted, or rather, a foundation for the good, well-prepared soil in which alone hawthorn plants will properly thrive. Fig. 64 represents a thorn-plant of six or seven years old, cut back nearly to the root, which is the state to which it must be reduced in order to form the future hedge. But while the young branches are thus entirely lopped, the root is kept as nearly as possible entire, and its fibres are spread out on the prepared soil in their natural position. The stem need not stand more than two or three inches above the ground: it usually sends out three or four strong shoots near the earth, and thus prepares for that close and thick growth near the base, which is a chief value of a hawthorn fence, and which, with the stiffness of its branches and the sharpness of its thorns, make it nearly impenetrable. If the thorn is to be a really handsome hedge, it must not be mixed with other plants in the hedge-row, nor overshadowed by forest trees. The old hedges in many parts of the country, in which trees are plentifully mingled, while they afford a delightful shade to the green lane or the dusty pathway, and are very pleasant and picturesque objects to look at, are nevertheless disadvantageous by their shade and drip to the fields on the other side, and have, indeed, been stigmatised as "the landlord's thieves." Still, there are exposed situations where belts of trees, planted as shelter for the crops or live stock, are very valuable and effective. When hedges have become old and overgrown, and are thin at the roots, it is desirable to cut them completely down, and let them sprout out anew (fig. 72). But if there are considerable gaps at intervals, it is better to cut down one fourth of the total quantity to the height intended for the fence, and then to bend and warp the remaining three-fourths of the upright stems, twisting them in amongst the rest, and thus supplying the gaps. This is called *plashing*. One of the most beautiful and durable of live fences is formed of the holly, but it is slow of growth, and requires protection until it has risen to a proper height; hence it will probably never become popular as a common farm fence, yet in some respects it would far surpass the hawthorn, being even closer of growth and more prickly, and having the great advantage of not losing its leaves in winter.

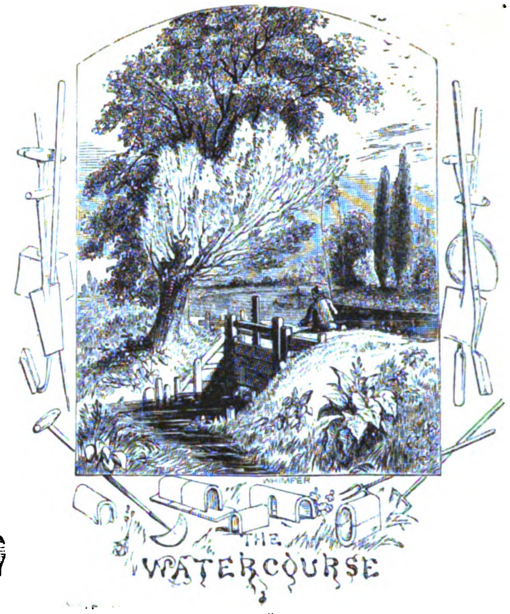
Draining and Irrigation.—Another business of the winter months, is the restoring old drains and forming new ones in such portions of the land as suffer from superabundant moisture; and on the other hand, preparing for the conveyance of water to those which are in need of such enrichment. Stagnant water may either accumulate on the surface of land, after heavy or long continued rain or snow, or it may lie hidden far below the soil, being fed by secret springs, and giving no other token of its presence than the unhealthy character of the land and crops. The system of drainage, therefore, must be adapted to meet these opposite conditions, and must be either *surface-draining* or *deep-draining*, as the case requires. Surface-drains are of two kinds, *open*, and *covered:* the former are mere gutters with sloping sides, made in the hollows and lower parts of land, and proportioned in size to the quantity of water to be carried off; the latter are trenches two or three feet, deep in which stones, rubbish, or draining-tiles are inserted, so as to keep a way open for the water to escape, while the earth is covered in on the surface, and no outward token of the drain is apparent, except in its effects. Sometimes a conduit is formed in a rough way by placing dry stones in such a manner as to leave a cavity at the lower part of the drain. Flat stones are laid along the top of this cavity, and other stones laid in above that, as shown at fig. 67; over this, a layer of straw, heath, or furze, and then the soil, which is heaped up a little on the surface, because it always sinks afterwards. Another form of conduit is shown at fig. 73. But the work is more effectually performed by means of *draining-tiles*, which are of various forms and degrees of efficiency, and which are less liable to displacement than any mere arrangement of stones and rubbish. The draining-tile may be of the shape which a common roof-tile would be, if we could bend it down at the two sides and make a half-cylinder of it; the objection to this form is, that when laid at the bottom of the trench, the two sharp sides resting on the clay, there is a tendency for the tile to sink, until the arch which it forms is quite filled up with clay, and the purpose of the drain defeated. To obviate this, a *sole* or flat piece is attached to the tile, as shown at fig. 83, but this increases the expense. In places where slate is plentiful, pieces of that substance are laid along the bottom of the trench, and the tile placed upon them, which prevents the sinking above referred to. But a contrivance is now common, uniting sole and tile in one, the tiles being made in the form of simple cylinders called *pipe-tiles*. Here there was the danger of their slipping apart at the joints, to prevent which, the ends of the cylinders were lobed, or made in a wavy line, as at fig. 70, or they were embraced by a collar as at fig. 75. A cheaper kind of pipe-tile, however, is that which unites tile and sole, and of this also there are several varieties, one of which is shown at fig. 68. The manner of working is as follows:—a trench is made as before mentioned, and its sides and bottom are neatly finished off by means of the narrow *drain-spade* (fig. 66), and the *drain-scoop* (fig. 71). The workman stands constantly in the trench, an assistant hands him the tiles, &c. which he requires, and he fits



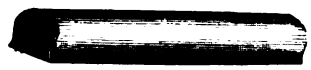
65.

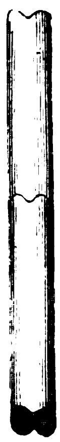

66. NARROW DRAIN-SPADE.

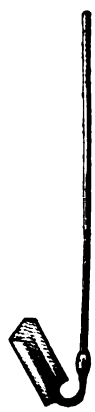

67. DRAIN WITH CONDUIT.



69.


68. IMPROVED FORM OF PIPE-TILE.


70. PIPE-TILE, WITH LOBED ENDS.

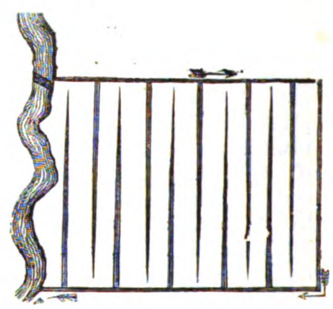

71. DRAIN SCOOP.


72. HEDGING AND DITCHING.


73. ANOTHER FORM OF CONDUIT.

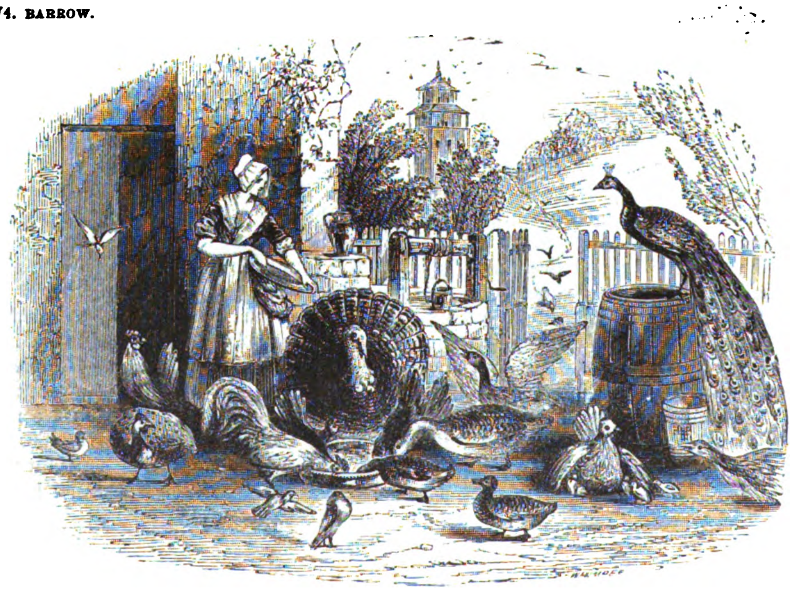

74. BARROW.


75. PIPE-TILE, WITH COLLAR.


76. COMMON FORM OF WATER-MEADOW.


77. DITCHER'S SHOVEL.


78. SECTION OF A RIDGE WITH FEEDER AND TWO DRAINS.


79. FEEDING POULTRY.

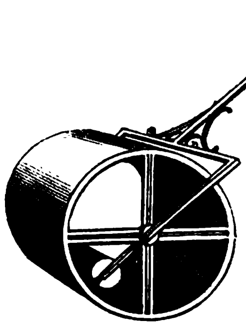

. AUGER.


81. PUNCH.


82. JUMPER.

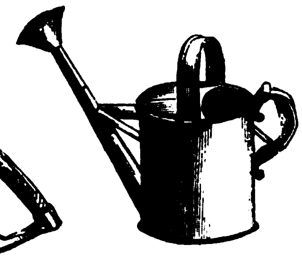

83. DRAINING-TILES, WITH SOLES.

THE GARDENER.



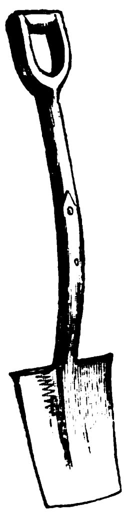
84. ROLLER.

85. SCYTHE AND RUBBISH BASKET.



86. WATERING POT.

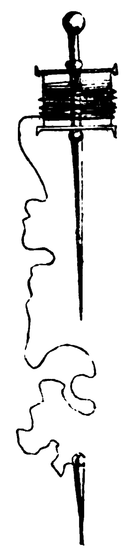
87. PRUNING KNIFE.



88. SPADE.

89. BUDDING KNIFE.

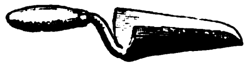
90. FLOWER GARDEN.



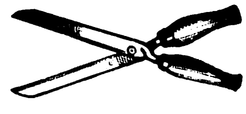
91. GARDENER'S LINE.

92. POTATO-FORK.

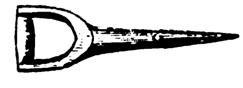
93. GARDEN RAKE.



94. TROWEL.



95. SHEARS.



96. DIBBLE.

97. HOES.

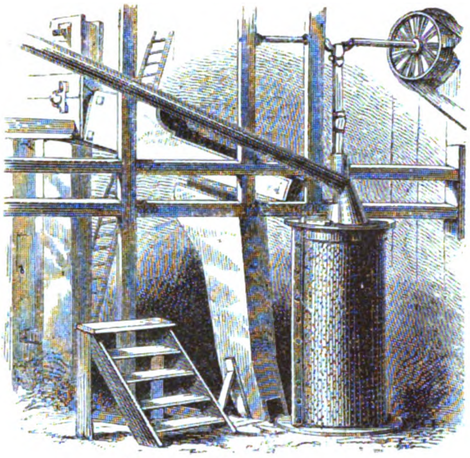
them in their position at the bottom of the drain, securing them in their places by pressing the earth firmly round them and filling up the trench. The mouth of the main drain where the water is discharged, is protected by masonry and an iron grating. Smaller or branch drains are formed in the same way, with a very narrow drain-spade and smaller tiles. Deep-draining is the same in principle, but the drains are fewer, and much deeper, and more extensive. The work requires to be superintended by scientific hands, for deep-draining is a serious and expensive operation, and if carrried on without sufficient knowledge and judgment, it may be mischievous rather than beneficial. Sometimes not even a drain of six feet deep will reach the seat of the water which is doing mischief to the land; it then becomes necessary to use boring irons, such as the common auger, a sharp pyramidal punch, and a chisel or jumper (figs. 80, 81, 82), by which means the clay is pierced, and the water, if reached, wells up into the drain and so passes off. Some of the benefits of thorough drainage are thus described by a practical agriculturist:—"On drained land, the straw of white crops shoots up steadily from a vigorous braid, strong, long, and at the same time so stiff as not to be easily lodged by wind and rain. The grain is plump, large, bright-coloured, and thin-skinned. The crop ripens uniformly, is bulky and prolific; more quickly won for stacking in harvest; more easily thrashed, winnowed, and cleaned, and produces fewer small and light grains. The straw also makes better fodder for live stock. Clover grows rank, long, and juicy, and the flowers large and of bright colour. The hay weighs heavy for its bulk. Pasture grass stools out in every direction, covering the ground with a thick sward, and produces fat and milk of the finest quality. Turnips become large, plump, as if fully grown, juicy, and with a smooth and oily skin. Potatoes push out long and strong stems, with enlarged tubers, having skins easily peeled off, and their substance mealy when boiled. Live stock of every description thrive, show good temper, are easily fattened, and of fine quality. Land is less occupied with weeds, the increased luxuriance of all the crops checking their growth. Summer fallow is more easily cleaned, and much less work is required to put the land in proper order for the manure and seed; and all sorts of manures incorporate more quickly and thoroughly with the soil." But it must be observed, that although such results as these follow the removal of *stagnant* water, yet the land requires constant supplies of moisture as the great means of nourishment, of healthfulness. The rains which occur so frequently in our own country are in many cases sufficient to supply this want; but in parts of the world where rain only occurs at very distant intervals, the land would become a barren desert were it not for the industry of the inhabitants in watering it by artificial means. In the neighbourhood of great rivers this is accomplished with comparative ease; and it has even been suggested that the overflow of such streams, and the subsequent fertility of the land which had been flooded, first gave the idea of artificial irrigation. In various parts of the world this art assumes an importance which it does not possess in this country, the growth and nourishment of the most important crops being dependent on it. In this country, water-meadows are indeed valuable, and a rich pasturage is thus supplied for our cattle; but irrigation is not required in order to make corn grow, or any other important crop of the year. The water-meadows of this country are managed with great skill, and the good effects of running streams instead of stagnant water have been fully proved. The manner in which they are arranged will be understood by consulting fig. 76, which represents one of the common forms of water-meadow. At the highest part of the meadow, a channel of considerable size is made, called the *main conductor;* this receives the water from the river, and distributes it over the meadow by means of channels or feeders at right angles with the main conductor. All these channels only provide for bringing the water into the meadow, but there is another and a precisely similar set of drains for carrying the water back into the river, so that between the two a constant flow is kept up. The feeders are formed on the top of low ridges (fig. 78), the drains in the hollows; and to keep the water at the necessary level, not only is its admission from the river regulated by a hatch (fig. 69), but smaller hatches or stops are placed in the feeders to interrupt its course. In forming these channels and drains the ditcher's shovel (fig. 77) again comes into use, and the earth dug from the trenches is wheeled away (fig. 74), to fill up hollows in other parts of the meadow. A barrier, called a *wear* or *dam*, is built across the river, in order to turn the water into the main conductor.

II.—THE GARDENER.

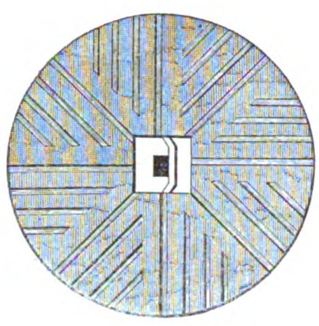
AKIN to the operations of the agriculturist, but on a smaller scale, are those of the Gardener, whose work is alike unceasing, and requires similar care and attention to render it successful. A great portion of his labour is indeed identical with that of the farmer, the only difference being in the tools employed. Instead of the plough he uses the *spade* (fig. 88), or the *potato-fork* (fig. 92); instead of the harrow, the *rake* (fig. 93); instead of sowing by the horse-drill, he puts in his seed by hand; and instead of collecting the fruits of the ground by scythe or sickle, he gathers them as occasion may demand, and leaves uninjured the stalks or branches on which they grow.

Digging, when well performed, is perhaps a more thorough disturbance and renewal of the soil than can ever be effected by the plough. The layer of earth is not simply turned aside, as in ploughing, but is completely turned over, so that the portion which has been partially exhausted by nourishing the plants, is brought to the surface; while that which has been renovated by exposure to the air, is sent down to supply fresh nourishment to the crop. *Raking* is again a more complete operation than harrowing, from the circumstance that the rake is not merely passed over the soil indiscriminately, but is worked backwards and forwards according to the judgment of him who wields it, stones being removed, while clods are broken by using the back of the rake to crush them. *Hoeing* is an expeditious way of removing weeds, and is performed either with the *common* or the *Dutch hoe*, both of which are shown at fig. 97. The common hoe has a flat iron blade fixed at the end of the handle, in the same position as the teeth of a rake. The Dutch hoe is a stirrup-shaped iron at the end of a long handle, and is used with less exertion than the former. Hoeing requires skill to remove weeds, and to leave the plants near them uninjured. The hoe must always be followed by the rake. *Planting* is performed by means of the *dibble* (fig. 96), when the plants are small, and is one of the most successful modes of cultivation; so much so, that in some places where labour is plentiful, it is adopted for field crops. In the smaller operations of the garden, where young plants have to be inserted in rows and at regular intervals, some other guide than the eye is required, and the gardener's *line* (fig. 91) is found very useful in preserving the neatness and uniformity of the beds. This is a long line fastened to and wound upon a spiked reel, and having a spike also at the other extremity. The spike is driven firmly into the ground, and enough of the line is unwound to reach to the place where the line is to be fixed. The spike of the reel is here inserted, and the tightened line serves as a sure guide. Where plants require to have the earth kept about them during removal from one bed to another, the *trowel* (fig. 94) is a most useful little implement; it also serves many other purposes, such as filling flowerpots with mould, &c., much more conveniently than the spade. *Watering* succeeds planting as a matter of necessity, and it should be sufficiently abundant to saturate the earth all round the plants. The *watering-pot* (fig. 86) should be furnished with two or three moveable tops, or "roses," with holes of various sizes for different crops; small and delicate plants requiring a fine spray, while larger ones will be all the better for a copious shower. As a general rule, watering should be performed in the evening, the plants thus enjoying its reviving effects for some hours before the sun returns to dry the soil. Plants growing in pots should also be thoroughly watered, but not allowed to stand in pans of water. Such pans are necessary to prevent injury in the house, but they should be emptied of water when it accumulates in them. The processes of *pruning* and *grafting*, already spoken of in connexion with the orchard, are part of the gardener's work. The knives used are represented at figs. 87 and 89. Lastly, for the improvement of lawns and garden-paths, there are the *scythe* and *rubbish-basket* (fig. 85), and the *garden-roller* (fig. 84).

The skilful employment of all these auxiliaries produces the neat and orderly appearance so characteristic of our flower-garden (fig. 90). Not less orderly, nor less industriously kept, are the market-gardens in the neighbourhood of London, which supply that vast capital with its regular amount of vegetable produce. In these gardens, the ground is never allowed to remain idle; vast crops of cabbage cover the earth in October; when these are removed, celery and lettuce immediately take their place; after these come winter-greens, then (in spring) onions, more cabbage, cauliflowers, cucumbers, French beans, and scarlet runners. The enormous supplies required, make it a matter of astonishment that they are so equably and constantly met. Potatoes, at the rate of three thousand tons per week, and all other vegetables in proportion, are brought spontaneously to the capital, and readily disposed of; and even such an insignificant article as watercresses is supplied, we are told, at the rate of seven or eight hundred tons annually. No doubt the healthy state of the metropolis is greatly due to this constant and abundant supply of *fresh* vegetable produce, which the railway system also vigorously promotes by taking off again the overplus of the London markets, to be sold at a cheap rate elsewhere. Thus we were astonished a short time since, to find in a city nearly one hundred miles from London, fruits from "yesterday's" Covent Garden market, selling at a rate which brought down the exorbitant demands of the country dealers in the same article.

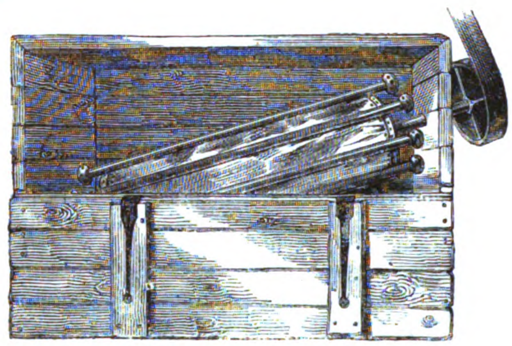


98. SMUT MACHINE.

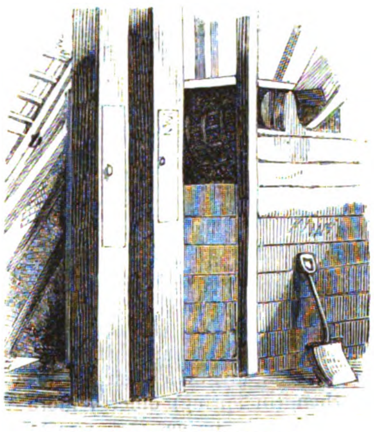


99. MILL STONE.

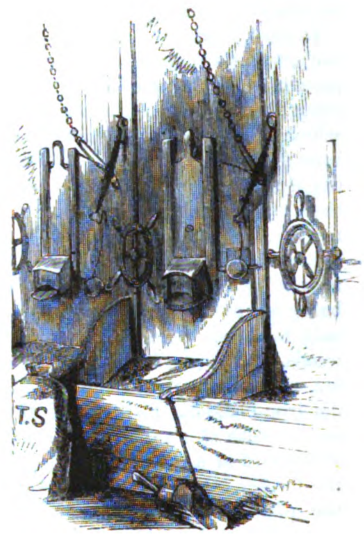
100. BOLTER.



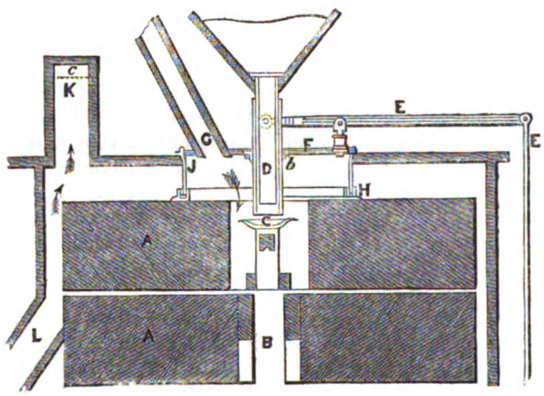
102. THE BOLTING MILL.



101. REVOLVING SCREEN.



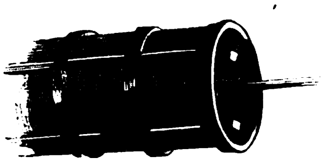
103. TROUGHS.



104. IMPROVED METHOD OF GRINDING.

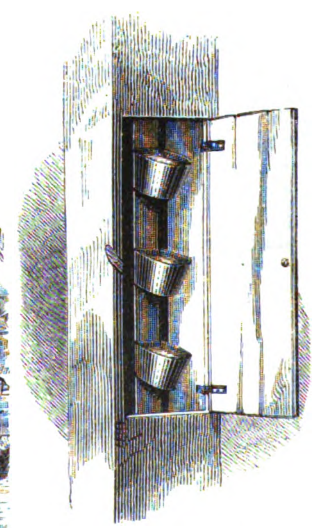
105. CLAW.

106. SCOOP.



107. DRESSING MACHINE.

108. CORN MILL.



109. "JACOB'S LADDER."

III.—THE MILLER.

The trade of the Miller is a very important one, since by means of it, the first step is taken in preparing wheat for use. There is no article so well adapted for the food of man as bread. It contains all the ingredients necessary for forming and sustaining the three principal solids of the human body, viz. the fat, the muscle, and the bone; and hence it is that a wise Providence has scattered wheat so widely over the earth, that most nations are acquainted with it in some of its varieties. Wheat consists of starch and gluten, together with a little sugar and albumen. It is the business of the miller to grind the wheat to flour, and otherwise prepare it for its intended use; and the building in which he does this is often picturesquely situated by the side of a stream, commanding a head of water for turning the water-wheel which drives the machinery, as in fig. 108; or the mill may be situated on a hill or breezy down, where the wind gives motion to sails which drive the machinery, as in the common windmill; or, thirdly, if the mill be situated in a large town, and the operations be conducted on an extensive scale, the steam-engine is the prime mover.

The most essential part of a corn-mill is a pair of millstones, circular in form, and placed one above the other, but not sufficiently near to touch. The lower or *bed*-stone is fixed, and from its centre rises a spindle, on which the upper stone, called the *runner*, moves. This spindle is moved by means of cog-wheels in gear with it, and connected with the prime mover. In the centre of the upper stone is a hole, through which the corn passes to be ground. The flat faces of the stones are cut into furrows (fig. 99), which allow the flour to escape, as the wheat is ground by the action of the stones. The stones are covered in by means of a large wooden case (fig. 100), opening at the bottom by means of a shoot into troughs (fig. 103) in the floor below.

There are several varieties of flour used in London: they are known as 1. *Best Flour*, or *Pastry Whites*; 2. *Whites*; 3. *Households*; 4. *Number* 2, or *Seconds*; 5. *Thirds*; 6. *Fine Middlings*. There is also *dusting* flour, used to give a fine colour and texture to the outsides of loaves. Each of the above varieties is produced by the admixture of several different kinds of wheat, well known to the miller, as the variety of flour is to the baker. For example: wheat containing much gluten may be mixed with one that contains abundance of starch; a red wheat may be mixed with a white one; a moist wheat with one that is dry; and so on. The art of *mealing*, as it is called, consists in the judicious choice of the wheat, and in the proper arrangement of the machinery, so that the whole of the flour which the wheat is capable of producing may be obtained at one grinding. The proper proportions of wheat for grinding are mixed in a bin, after which the grain is passed through a blowing apparatus, in order to separate dust and light particles. It is next passed through a *smut* machine (fig. 98), consisting of iron beaters enclosed within a skeleton cylindrical frame covered with wire; the spaces being wide enough to allow the impurities of the grain to fall through. The beaters revolve 400 or 500 times in a minute, and by their action against the wires scrub the wheat, and remove portions of dust, smut, and impurities. After this, the wheat is passed through a screen, arranged spirally on a horizontal axis, the revolutions of which scatter the seeds over the meshes, and allow small shrivelled seeds to pass through. The grain is next exposed to a current of air from a fan, which completes the removal of chaff, dirt, smut-ball, &c. The result of all this elaborate cleaning is greatly to improve the whiteness of the flour, and also its wholesomeness; and its necessity is evident from the accumulation of impure matter in the cases of the screens. As the wheat passes from the last cleaning machine, it falls down a canvas tube into the hopper which supplies the millstones (fig. 100), where a jigging kind of motion is kept up, so as to shake the corn into the trough over the stones in equable quantities; and so long as this action is going on properly, a little bell is made to ring, the motion of which ceases with the supply of wheat.

It has been already stated that the stones are boxed in to prevent the flour from being scattered by the centrifugal force of the runner. According to the old method, this is done very imperfectly, so that there is a considerable loss of fine flour; which fills the air of the mill, covers the men, and injures their health by being continually breathed. These evils are remedied by the improved method of grinding, represented in fig. 104. According to this plan, the stones are completely boxed in, and a blast of air is directed upon the grinding surfaces for the purpose of keeping the stones cool, and removing the flour as fast as it is formed, the effect of which is that eight bushels of wheat can be ground per hour, while by the common method only four are produced; at the same time, the flour is improved in colour, and the usual waste avoided. In fig. 104, *AA* show the stones in vertical section, the lower edge of the runner at *A* being bevilled to admit the air-blast. *B* is the driving spindle on which the cup *C* is attached, for receiving and distributing the grain from the telescope feed-pipe *D*, which is regulated by a lever and rod *E*. The centre of the stone-case is closed by an iron plate *F*, with apertures for receiving the blast-pipe *G* and the feeding-tube *D*, a leathern ring at *C* making the joint tight. The blast is supplied to *G* by means of a fan or a blowing machine. At *H* is a grooved iron ring attached to the top of the runner, while at *I* is a circular leather inserted in the groove; the object of which is to prevent the blast or the grain from passing otherwise than through the centre of the runner. It will be seen by the arrows, that the blast must remove the meal as soon as it is produced, and send it down the shoot *L*, while any waste which would otherwise escape into the air, is collected in the waste air-pipe *K*. After the blast has served its purpose, it is conveyed into a closet lined with woollen cloth, through which the air filters, leaving behind fine particles of flour, which would otherwise escape into the mill.

The ground grain is usually separated into three parts, viz. the *flour*, the *pollard*, and the *bran*. The bran is the outer husk of the grain, and is given to horses and cattle; the pollard is the part next the husk, and is coarser and darker than the flour, which forms the interior or central portions of the grain. The meal is dressed or separated from the bran by means of the dressing machine (fig. 107), consisting of a hollow cylinder in a slanting position, covered internally with wire-cloth of varying degrees of fineness. Within the cylinder is a revolving reel with brushes attached; which, working against the wire-cloth, cause finer portions of the meal to pass through. The meal is usually conveyed from the lower part to the upper part of the mill to be dressed. This may be done in sacks, or by the contrivance shown in fig. 109, called a *Jacob's ladder*, consisting of tin vessels attached to an endless band, which, filling themselves in the trough below, pass up a shoot, discharge their contents above, and descend to be filled again. The finest of the flour passes through the upper end of the dressing machine, which contains the finest wire-cloth; the next finest flour passes through the next division, the *middlings* through the next, and lastly, the pollards, or *sharps*, through the last division; while the bran, being too coarse to go through any of the divisions, is discharged at the lower end of the cylinder. The apparatus is enclosed in a case, as in fig. 101, the lower part of which is divided into bins for receiving the different qualities of flour.

The dressing-machine is an improvement on the *bolting mill* (fig. 102), which is still in use in rural districts. It consists of a long reel lined with a peculiar kind of cloth, made to revolve rapidly so as to be acted on by a number of bars, called *beaters*, which strike against the cloth, and cause the finer portions of

the meal to pass through. In order to have flour of different degrees of fineness, different bolting cloths must be used. In the best mills, the meal is dressed by means of *silk-machines*, each of which consists of an octagonal framework of wood moving on a central axis. The spaces of the framing are covered with silk of peculiar texture. The ends of the machine are open; and the axis being inclined three quarters of an inch to each foot of the length of thirty-six feet, and the meal being poured in at the upper end, each of the eight sides of the frame acts in turn as a sieve as the frame revolves. In order to prevent the silk from being stopped up by the flour, the radial arms of the frame are furnished with stout rings of wood, which fall backwards and forwards between the axis and circumference of the frame as it revolves, and impart a vibratory motion to the silk, which assists the passage of the fine flour. The pollard, bran, &c. which do not pass through, fall out at the lower extremity of the machine, and are conveyed to other dressing-frames.

The flour which is separated from the dressing-machine is a finished product; the middlings are passed through a bolting-mill, whereby three qualities are produced, viz. *fine middlings*, *coarse middlings*, and *thirds flour*. The first of these is used for sailors' biscuits, the second for feeding pigs, &c., while the third is sold as thirds flour. Seconds flour is produced from an inferior wheat. The *refuse*, or *offal*, is passed through a *jumper*, or frame of wire-gauze, of various degrees of fineness, whereby it is separated into *superfine pollard*, *fine pollard*, *course pollard*, and *bran*.

The advantage of the improved method of grinding (fig. 104) is that, by keeping the meal cool, it can be immediately dressed; whereas, by the common method, it has to be kept in sacks for some weeks before it is fit for dressing. In carrying a sack, the man assists himself by means of a *claw* (fig. 105), while the *scoop* (fig. 106) is used in weighing out small portions of flour, or taking up samples of grain.

IV.—THE BAKER.

The baker procures his flour from the miller; and the first operation in the making of bread is to mix the flour in the kneading-trough (fig. 114) with about half its weight of water, but the proportion varies with the quality of the flour. The baker kneads the flour and the water together with his hands and arms into a stiff paste called *dough*, with the addition of a small portion of *yeast* and salt, when he leaves the mass for some hours at a temperature of about 70°. During this time the dough swells up, or, as the baker calls it, the *sponge* rises. The reason for this is, that the sugar of the dough becomes decomposed by the yeast; and a gas called *carbonic acid* is set free at all points of the dough, and being imprisoned by it, the gas makes it swell and become porous. It is now cut into pieces by means of the knife (fig. 117), and weighed at the scales (fig. 110), and put into the oven by means of one of the *peels* (figs. 116, 120); the oven having been previously cleaned out by means of a net or *swabber* attached to the end of a pole (fig. 112). The dough is heated to between 450° and 500°, when the imprisoned gas expands still more and gives that lightness of texture which belongs to good bread. The effect of the heat is to drive off a portion of the water of the dough, 117 parts of which become 100 of bread; while the starch passes into the pasty condition. Although so great a heat is employed, the temperature of the crumb does not rise above that of boiling water, or 212°, but the external surface of the loaf gradually becomes dry and hard; it loses a further portion of its water, and forms the *crust*. The bread thus becomes fixed in the shape of a loaf. During the baking, the alcohol formed by the decomposition of the sugar is driven off.

On the Continent, *leaven* is sometimes used to make the bread rise instead of yeast. Leaven is a portion of the dough kept from a previous *batch* in a warm place, until it begins to ferment of itself. The decomposition thus begun, spreads through the mass, when it is kneaded with fresh dough. A kind of unfermented bread is sometimes made by mixing carbonate of soda and hydrochloric acid with the dough; the acid sets free carbonic acid, which gives lightness to the bread, while the resulting chloride of sodium takes the place of common salt, with which it is in fact identical. The following proportions may be used for this kind of bread:—wheat flour 7lbs., carbonate of soda 350 to 500 grains, water 2¾ pints, and hydrochloric acid 420 to 560 grains. The flour and the soda are first well mixed, and then made into dough by means of the water and the acid. Pastry is sometimes made spongy and light by means of carbonate of ammonia, which is mixed with the dough instead of the yeast: the effect of the oven is to drive off the salt in the gaseous state, which produces the effect required.

In London there is a great prejudice in favour of white bread, which is not, however, so nutritious as what is called *household-bread*, from which only the bran has been separated. In order to produce white bread and to improve the tenacity of the dough of inferior flour, a small portion of alum is used. It has been pointed out by Liebig, that when flour has been injured in such a way as not to form good bread, the addition of a little lime-water will restore its good qualities, and get rid of that objectionable substance, alum. The baker is also in the habit of mixing potatoes with his bread, under the idea that it improves its quality. The quantity is usually not more than 8lbs. to a sack of flour, which weighs 280lbs., although in some cases a larger quantity is used.

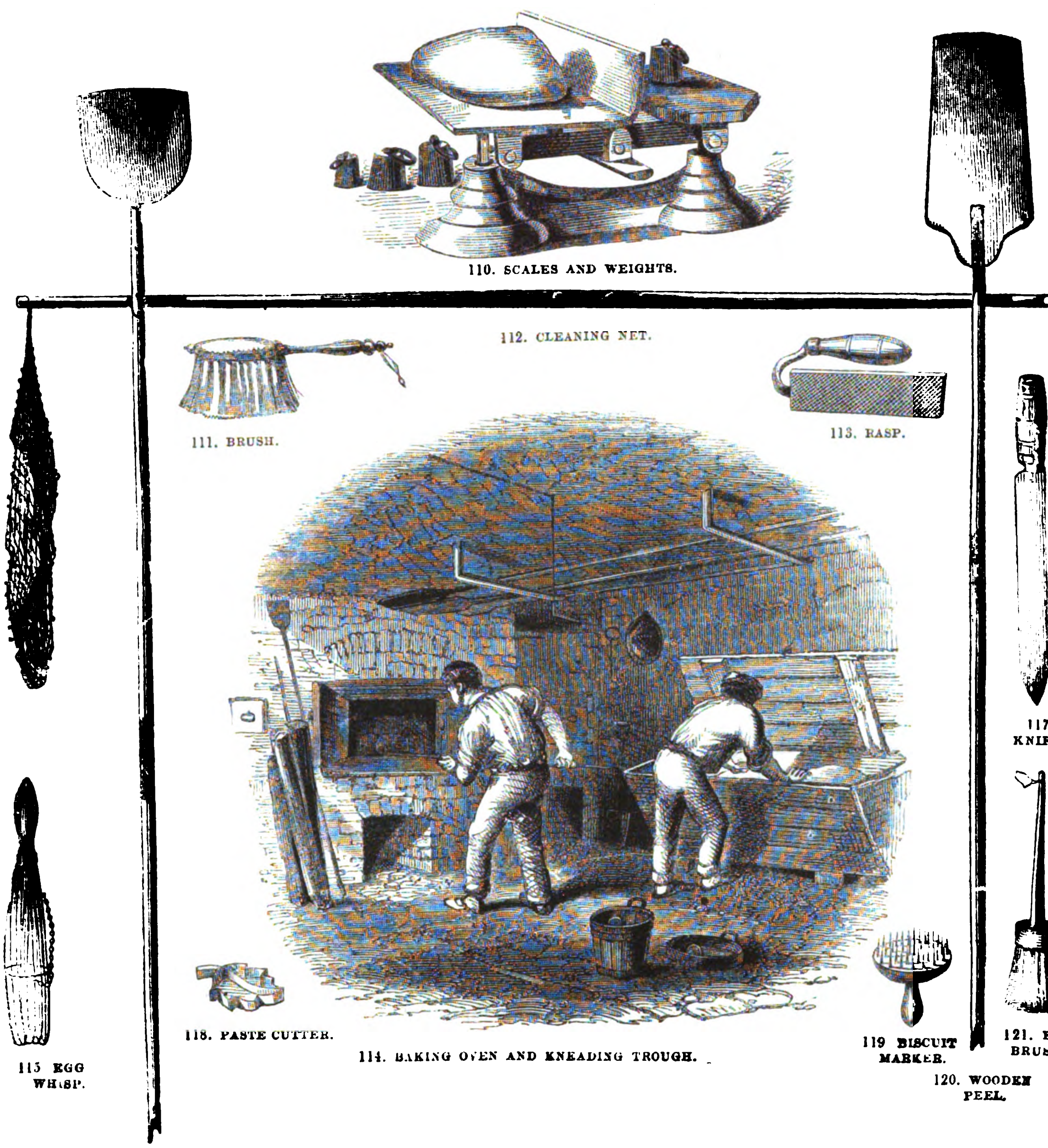
Newly-baked bread when cold contains about 45 per cent. of water, nor does stale bread contain a less quantity. Stale bread may be brought back to the condition of new bread by placing it in the oven for an hour. This effect may be seen on toasting a thick slice of stale bread, when the crumb will be found in the same state as that of new bread.

A sack of flour weighing 280lbs. and containing 5 bushels, generally produces 80 loaves. According to this, one-fifth of the loaf consists of water and salt, and four-fifths flour; but the number of the loaves depends on the goodness of the flour. Good flour requires more water than bad, and old flour more than new.

Fancy-bread is made of the finest flour, and is sometimes cut out into fanciful forms with a paste cutter, one of which is shown in fig. 118; while *biscuits* are sometimes marked with a series of points (fig. 119), to allow the heat to penetrate better (the word "biscuit" being from the French *bis* and *cuit*, signifying "twice cooked" or "baked"): while some kinds of bread are baked in tins (figs. 122, 123). The hard dark crust of rolls is removed by means of a *rasp* (fig. 113), while a smooth glistening surface is given to other articles by means of egg or butter, the egg being beaten up with a *whisp* (fig. 115), and applied by means of a *brush* (fig. 121).

The *basket* in which the baker carries his flour is lined with tin, as in fig. 124, and the *scoop* with which he takes up small portions of flour is shown in the same figure. The *sieve* for sifting the flour (fig. 125) is made of wire, but he also uses a *seasoning sieve*, made of hair, for straining the water, the yeast, &c.

In London, the oven is heated by means of coals burnt in a fireplace on one side, and the heat is communicated by a flue winding round the oven. The baker judges that the heat is sufficient when some flour thrown on the floor of the oven blackens without taking fire.



110. SCALES AND WEIGHTS.

111. BRUSH.

112. CLEANING NET.

113. RASP.

114. BAKING OVEN AND KNEADING TROUGH.

115. EGG WHISP.

117. KNIFE.

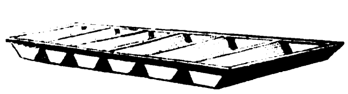
118. PASTE CUTTER.

119. BISCUIT MARKER.

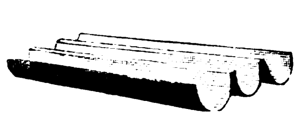
120. WOODEN PEEL.

121. EGG BRUSH.

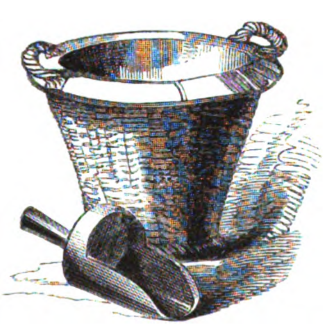
116. IRON PEEL.



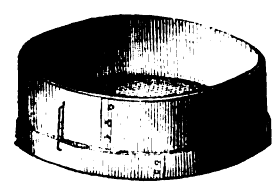
122. TIN FOR SPONGE CAKES.



123. TIN FOR FRENCH ROLLS.



124. FLOUR BASKET AND SCOOP.



125. SIEVE.

V.—THE BREWER.

Wine, beer, and such like drinks, are prepared by the chemical process of *fermentation*, which is subject to many variations, according to the nature of the beverage intended to be produced. A few words, however, on fermentation in general will make the processes of the brewer, the wine-grower, and the distiller, more clear. By the process of fermentation, a particular change comes over saccharine bodies (or those which contain sugar), whereby they become converted into carbonic acid and alcohol. Thus, when the sweet juices of plants or of fruits, such, for example, as the *must*, or juice of the grape, are kept for some hours at the temperature of about 70°, they become turbid, small bubbles of gas rise to the surface, and the liquid is said to be *working*, or fermenting. The change produced in the liquid is, in the first instance, formed in certain albuminous and azotised matters contained in the juice, under the influence of the oxygen of the air, warmth, and moisture. As the fermentation goes on, heat is given off, and carbonic acid gas constantly escapes. After a time, the liberation of gas ceases, and if the liquid be examined, the sweet taste of sugar will no longer be found, but the flavour of spirits will have taken its place. If the liquid be now distilled, the first portions that come over will be an inflammable substance, known as spirits of wine. If the liquid be examined when the fermentation is complete, it will be found to contain a substance called *yeast*, which consists of a multitude of small, oval, organised bodies, not exceeding $\frac{1}{250}$th of an inch in diameter. This substance, yeast, is formed in great abundance during the fermentation of the *wort* of beer, and it possesses in the highest degree the power of producing alcoholic fermentation. If, for example, 4 parts of cane sugar be dissolved in 20 parts of water, and 1 part of fresh yeast be added, and the mixture be exposed to a temperature of about 80°, fermentation will set in in less than an hour, and abundance of carbonic acid will be disengaged.

In the preparation of beer, the sweet solution is formed by means of *malt*. Malt is prepared from barley, which is put into large cisterns containing water, where it absorbs moisture, swells, and gives off carbonic acid. It is left in the water about forty hours; when it is taken out, and spread upon the malt floor in rectangular heaps, called the *couch*. Here it remains about twenty-six hours, during which time it increases in temperature, and parts with much of its moisture. In about sixty hours more, germination will have commenced: small roots appear at the bottom of each seed, and they rapidly increase in length, unless their growth be checked. For this purpose, they are spread out upon the floor and turned over several times a day, in order to lower the temperature. In about twenty-four hours, the rudiments of the future stem, called the *acrospire*, begin to appear. When this has come nearly to the extremity of the seed, the germination is stopped by drying the malt in a kiln. It is spread out on a floor of iron plate, drilled with holes, below which is a charcoal or coke furnace, and the hot air ascending through the floor, dries the malt and destroys its vitality. The malt is then passed through a screen, to separate the radicle; after which it is spread out so as to become soft and mealy by the absorption of moisture.

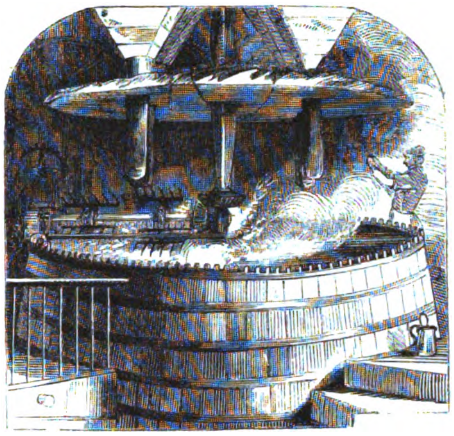
In the process of malting, sugar is not actually formed, but a peculiar azotised substance, named *diastase* (from a Greek word, signifying "to separate"), which possesses the remarkable property of converting the starch of the seed into a fermentable sugar, resembling cane-sugar, but not identical with it. This change, however, does not take place all at once; the starch is first converted into a gummy, mucilaginous substance, soluble in water, named *dextrine*, which does not ferment in the presence of yeast, but by the action of diastase becomes converted into starch sugar, which does ferment.

The next important ingredient in the preparation of beer is the *hops*. These are the seed pods of the female plants of the *Humulus lupulus*, a creeping plant of the family Urticeæ. It is cultivated in Kent, Sussex, and Hampshire. The active part of the plant, which is alone useful in making beer, is a yellow aromatic dust, formed at the base of the hop-flowers, or cones, and called *lupulin*. The cones are gathered before they are quite ripe, and are immediately dried in a kiln, at a heat not exceeding 86°. They are then strongly compressed by means of a hydrostatic press, and packed in canvas sacks, called *pockets*: the object being to exclude them from the air.

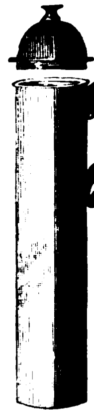
The first process in brewing consists in *grinding* the malt, which may be done either by means of mill-stones, steel mills, or iron rollers, the object being to crush rather than to grind; for if too fine, it would coagulate in lumps, and not be wetted by the water. The second process is called *mashing*. Water, at the temperature of from 160° to 170°, is drawn from the copper into a large vessel called a *mash-tun* (fig. 126), and when its temperature is ascertained by the thermometer (fig. 130) to be about 160°, a quantity of the crushed malt is shaken in, sufficient to absorb nearly the whole of the water, when it has been well stirred up by means of poles or oars, or of appropriate machinery, moved by the steam-engine, as shown in fig. 126. There ought to be enough water to wet the malt thoroughly, and to cause it to swell so as to dissolve the sugar, and to allow the diastase to react on the starch. When the malt has been completely wetted, the mash-tun is covered up, and left for about half an hour, when a second quantity of water at about 194° is added, with fresh stirring. The mash-tun is again covered up, and left for two or three hours. The liquor, now called *sweet wort*, is strained off into a vessel, called an *underback*. Water at 194° is next added to the mash-tun, forming what is called the "second mash," and when drawn off, it may be added to the first. The water for the "third mash" may be near the boiling point: this removes all the remaining soluble matter, and when drained off is usually set aside by itself for making small beer. The mash-tun is commonly furnished with a false bottom, perforated with a multitude of holes, and the tap for draining off the wort is set in the tub between the two bottoms.

After the wort has been drawn off, the spent malt retains about thirty-two gallons of water for every quarter of malt used. In the after processes of boiling and cooling, about forty gallons of water are lost for every quarter of malt, making a loss of seventy-two gallons of water per quarter; so that, if thirteen quarters of malt be used to produce 1,500 gallons of beer, 2,400 gallons of water will be required for mashing. To enable the brewer to brew beer of the same quality, he tests his worts by means of a *saccharometer* (fig. 129). It is a species of hydrometer, consisting of a hollow copper-ball, with a weight attached to the foot stalk, and a flat, graduated stem proceeding from the upper part, and so adjusted that, on being placed in water, it shall sink to a certain line, called the *water-line*; but on being put into a liquid heavier than water, it does not sink so much; so that, if the instrument sink in two different worts to the same mark, the brewer judges those worts to be of the same strength; and if it sink to different heights, he is able to calculate by how much one wort is stronger than another. Fig. 128 represents the can used with the saccharometer for testing the different worts.

When the worts are adjusted to the proper strength, they are pumped from the underback into the copper (fig. 136), shown in section, fig. 131, while the stoke hole of the furnace is shown in fig. 134. The copper is a close vessel, with a valve at the top, loaded so that the temperature may be somewhat higher than the boiling point of water, or 212°. As soon as the wort is introduced, the proper proportion of hops is added, and the boiling is continued until the mixture becomes clear. To prevent the hops from burning by settling to the bottom, the mixture is well stirred by means of a chain called a *rouser*, hung from a bar which is supported by an upright rod, passing out of the copper through a stuffing-box at the top, where it is in gear with the bevelled tooth-wheels by which it is driven (fig. 131). The quantity of hops used depends on the strength of the beer. For strong beer, four and a half pounds of hops to the quarter of malt is sometimes allowed. For the stronger kinds of ale and porter, it is usual to allow one pound of hops for every bushel of malt, or

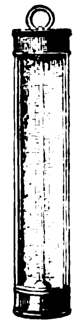


126. MASH TUN.

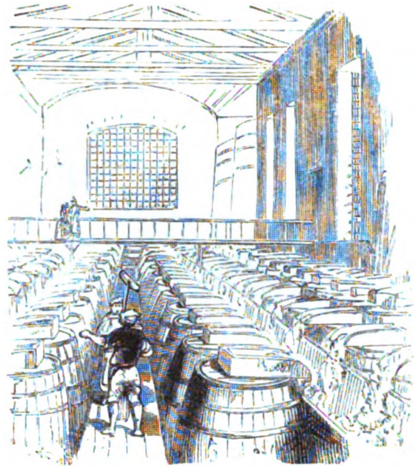


128. SACCHARO-METER CAN.

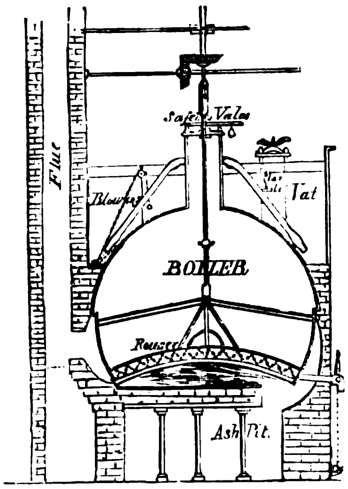
129. SACCHARO-METER.



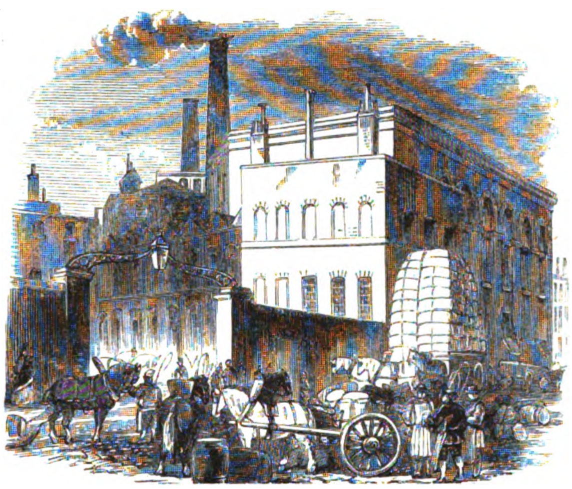
130. THERMOMETER.



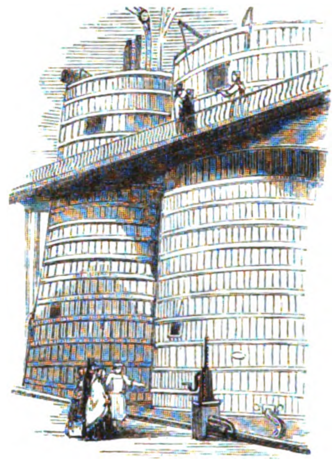
127. CLEANSING VATS.



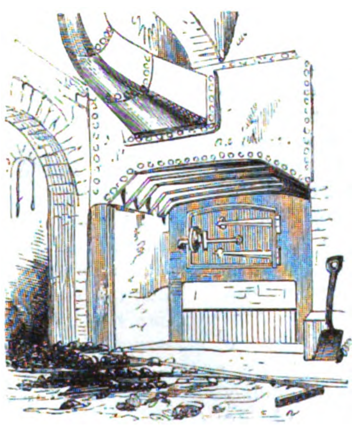
131. SECTION OF BOILER.



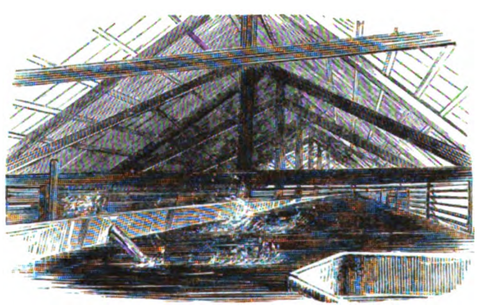
132. BREWERY.



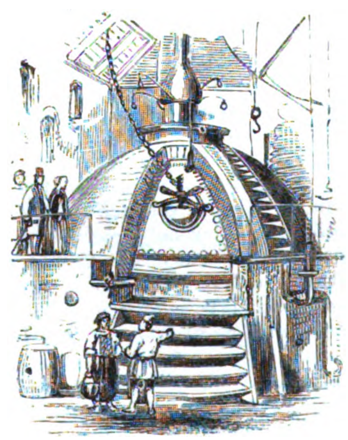
133. STORE VATS.



134. STOKE HOLE.



135. COOLER.



136. TOP OF BOILER.

eight pounds to the quarter; but for common beer, not more than a quarter of a pound of hops to the bushel is allowed.

When all the bitterness of the hops has been extracted by the boiling, the worts are let down into a vessel with a metal bottom, full of small holes, called the *hop back*, where it is separated from the hops. The liquor is then pumped up into the *cooler* (fig. 135), which is a shallow vessel of considerable extent, usually situated at the top of the brewery, and exposed on all sides to a current of air; the object being to cool the liquor as quickly as possible, to prevent souring or *foxing*, as the brewers call it. In some cases, a large horizontal fan is made to play over the surface of the worts, to expedite the cooling. When the worts have cooled down to about 55° or 60°, they are received into a large vat called the *fermenting-tun*, where a quantity of yeast is added, varying with the strength of the wort and the time of the year; but usually one gallon of yeast is sufficient to produce fermentation in 100 gallons of wort. In the course of a few hours, a frothy ring may be seen to leave the sides of the tun, and to proceed a few inches towards the centre; this is succeeded by another and another ring, until, at length, the whole surface becomes covered with a thin, creamy froth. A slight hissing noise is also heard, owing to the breaking of innumerable bubbles of carbonic acid gas on the surface. The froth rises higher and higher, forming abrupt elevations, called by the brewer *rocks*. The colour of the froth passes from white to yellow, and often to brownish yellow. The froth becomes more viscid, and forms larger bubbles of gas, causing the head to foam and sink in turns. After some hours, the head begins to flatten and subside, and the thick yeast, having parted with its gas, would soon fall to the bottom, unless skimmed off. During this *vinous* fermentation, a portion of the sugar of the wort is converted into alcohol; but if the yeast were allowed to sink, the effervescence would soon cease, the liquor would become transparent, and soon after, a new set of changes would set in, producing the *acetous* fermentation, and the liquor would be converted into vinegar. To prevent this, and to cleanse the beer of the particles of yeast which are floating through it, it is racked off into a number of casks called the *rounds* (fig. 127), in which the vinous fermentation is completed. During this operation, carbonic acid is liberated, and this, attaching itself to the suspended particles of yeast, carries them up to the bung-hole, where both are expelled. The bung-hole of each cask has inserted into it a short wooden pipe, terminating at the top in a sloping tray, which pours the yeast into a wooden trough, as shown in fig. 127. The rounds are kept always full, to facilitate the escape of the yeast. When the fermentation is over, the beer is pumped up from the rounds into immense *store vats* (fig. 133), (some of which contain upwards of 1,500 barrels,) where it is kept to ripen, or until it is drawn off into casks for sale. In the case of ale, however, the cleansing is carried on in the casks in which the liquor is sent out. When the cleansing is complete, the casks are bunged tightly down, to retain a portion of the carbonic acid, which gives to the beverage the brisk, foaming head, so much admired. The quantity of alcohol in common strong ale or beer is about 4 per cent.; in the best brown stout, 6; in the strongest ale, 8; but in common beer, not more than 1 per cent. Beer also contains gum, sugar, and starch gum in solution; also aromatic matters, lactic acid, various salts, and free carbonic acid, varying from 2 to 25 per cent.

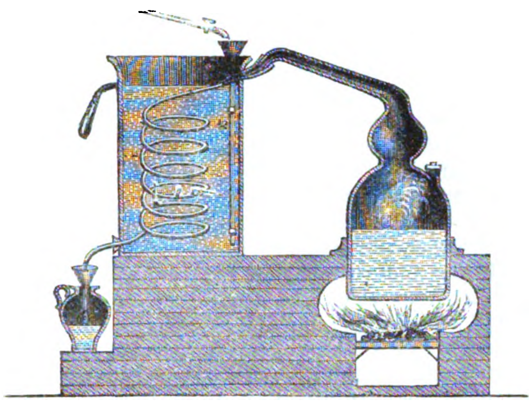
In some cases, the cleansing is hastened by the addition of a solution of isinglass in weak, sour beer. When this *fining*, as it is called, is poured into the cask, it forms a kind of web over the surface of the liquor, and gradually sinking to the bottom, carries all the flocculent matter with it, and leaves the beer transparent. If this be required for keeping, it is usually racked off into a clean cask.

Porter brewing differs from that of ale in the quality of malt employed. In the former, a high-dried, partly-burnt malt is used; and in the latter, a pale malt. The methods of brewing also vary in different parts of the country; there are also slight variations in the nature of the materials, especially in the water, which give to different kinds of malt liquor their peculiar characteristics. Domestic brewing differs only from that of the large breweries in the quantities employed. In the latter case, these are so vast as to constitute quite a national feature. In the year ended 10th October, 1857, the public brewers in England used 22,818,560 bushels of malt; those in Scotland, 1,062,723 bushels; those in Ireland, 2,083,934 bushels; while the small brewers and beer sellers used 10,487,936 bushels. In the same year also, there were exported from the United Kingdom 429,367 barrels of beer, of which the declared value was 1,573,722*l.*; while the number of acres used in the growing of hops was 50,975.

VI.—THE DISTILLER.

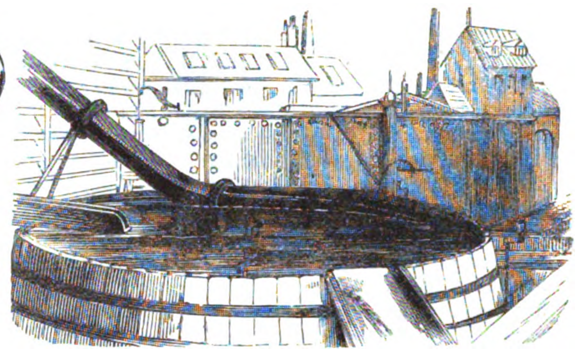
Distillation is the process by means of which one body is separated from another by means of heat. One of the bodies assumes the elastic form, or becomes converted into vapour at a lower temperature than the other, and is received and condensed in a separate vessel which is kept cold. When the vapour becomes condensed in the solid form, as in the case of camphor, sulphur, calomel, &c., the process is termed *sublimation*. Distillation is usually conducted in a *still* (fig. 137), which consists of a body, for the reception of the liquid to be distilled: a *head*, and a neck terminating in a spiral pipe or *Worm*, which is contained in a vessel of cold water called the *worm-tub* or *refrigerator*. The body should be made so as to present a large surface to the fire, and its depth should be small. The neck should be tolerably wide, so as to convey away the vapour as fast as it is formed; and so high, that the liquid in the still cannot boil over. The worm should enter on one side of the tub near the top, and then pass spirally in six or eight turns to the bottom, where it should come out of the side so as to discharge the liquid formed by the condensation of the vapour within it. As the water in the worm-tub becomes hot by contact with the worm, fresh supplies of cold water should be admitted near the bottom, while the heated water is flowing away at the top.

In the preparation of ardent spirits, the preparatory processes resemble in many respects those of the brewer. A saccharine solution or wort is made and fermented by means of yeast; but instead of allowing the spirit to remain in the liquor as in the case of beer, it is separated by means of distillation. In the different varieties of ardent spirits, alcohol, produced by the fermentation of sugar, is the intoxicating principle: the aroma, or flavour, which distinguishes one spirit from another, is due to the presence of an essential oil derived from the substance employed to furnish the saccharine solution. Thus the sugar-cane furnishes an oil which imparts the peculiar flavour to rum, which is obtained from the refuse of cane-sugar in the West Indies. So also the grape yields an oil which gives the flavour to brandy, and this is obtained by distilling wine in wine-growing countries. Gin, whisky, &c. are procured from malt or raw grain; the starch which forms a large proportion of barley is converted by the action of warm water into sugar, and this into alcohol. Grain contains a peculiar oil, most of which is separated during the rectification; but juniper berries are added in the case of gin, on account of their peculiar flavour.

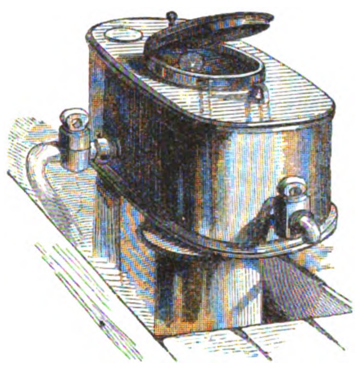


137. COMMON STILL.

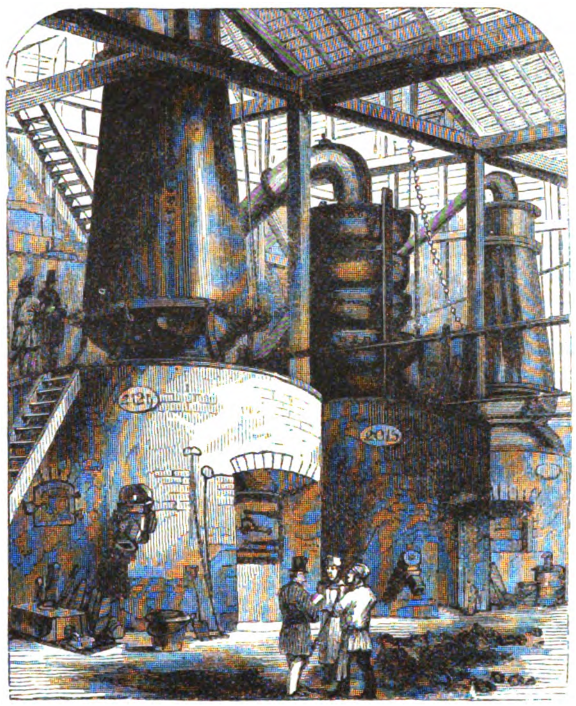
138. SPIRIT GALLON MEASURE.



139. TOP OF WORM TUB.



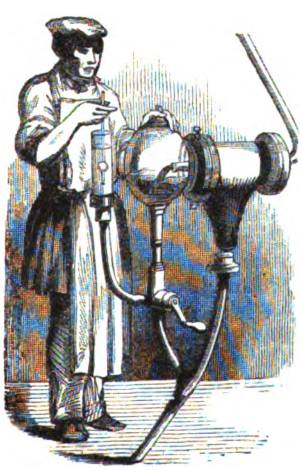
140. END OF WORM OF RECTIFYING STILL.



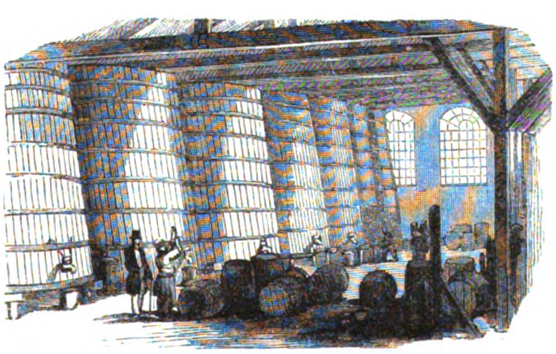
141. DISTILLERY.

142. NOZZLE.

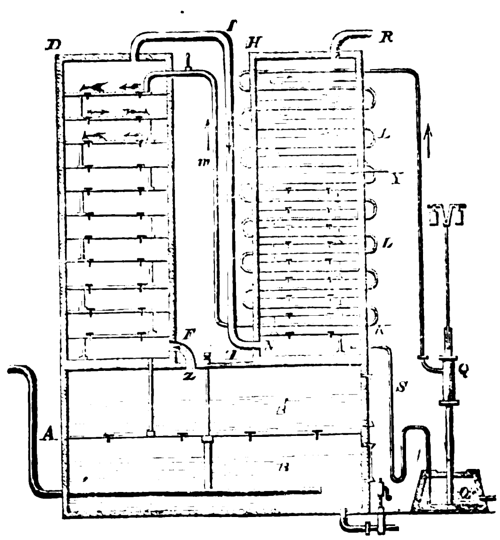
143. FUNNEL. 144. VELINCH.



145. PIPES AT THE WORM END.



146. STORE VATS.



147. COFFEY'S STILL.

In the preparation of whisky, for example, barley is employed with malt in small quantity in consequence of the duty thereon. The grain is ground to a fine meal in a mill with a certain portion of oats, which are crushed or rolled, to prevent the barley-meal from clogging. A small quantity of malt is added to saccharify the starch of the barley and oats. The mash-tun is of cast iron, and the water measuring 700 or 800 wine gallons is let in at the temperature of 150°. The mashing is continued from one to four hours, and about 500 gallons of water at about 200° are let in from time to time to keep up the temperature. The wort gradually increases in sweetness until it is drawn off, which is done near the surface. Fresh water is added and left for about half an hour to infuse, when it is drawn off. More hot water is added, so as to get everything soluble from the grain. The wort is cooled as quickly as possible, and yeast is added to set the fermentation going. This process is carried on during many days, and the yeast is left in the liquor. As the fermentation proceeds, the specific gravity of the wort diminishes, owing to the decomposition of the sugar and its conversion into alcohol and carbonic acid.

When the fermentation is complete, the *wash*, as it is now called, is distilled. The still resembles that already described (fig. 137). Spirit being more volatile than water, it passes over first in the form of vapour, and is condensed into a liquid in passing through the worm. The first portions are very strong, but as the process proceeds, the heat vaporizes a portion of the water also, and this is condensed together with the vapour of spirit, and towards the end of the process more water passes over than spirit. When it is found by means of a hydrometer (fig. 145), that the condensed liquid is about as heavy as water, the distillation is stopped, and the cock at the bottom of the still is opened, and the wash is let off; it is a muddy brown liquor, containing a portion of undecomposed saccharine matter, and is used as food for cattle.

In Scotland the weak spirit obtained by the first distillation is called *low wines:* it contains about one-fifth alcohol and four-fifths water. The low wines are distilled a second time, when the first portion that comes over is called *foreshot;* it has a milky appearance and a disagreeable taste from the presence of oil; it is returned to the still, and it is not until the condensed spirit flows off transparent, that it is collected. When the spirit has reached a certain density, as determined by the hydrometer, the product is collected in a separate vessel. This third portion is called *faints*, and is mixed with the low wines, and distilled again. The distillation of the low wines is continued until the whole of the alcohol is of the proper strength.

In addition to the spirit and the water which pass over from the still, there are certain essential oils which vary with the kind of grain or vegetable matter employed. Those from wine, or from the wash made from sugar, have an agreeable flavour and aroma, but the oils from malt and grain are very disagreeable; and when the old form of still is used, it is the business of the *rectifier* to remove them. The rectifier procures the spirit from the distiller in the state of *raw spirit;* the still employed by him is similar to that used by the distiller, but he applies his heat with more caution. When the oil is abundant, alkalies are added, which form soapy compounds, which do not pass over at a moderate heat. Acids are sometimes added, by which the oils form resinous compounds, whereby they become less volatile. In the rectification of gin, a few juniper berries and some hops are added, to give a peculiar flavour to the spirit. The Dutch are celebrated for the manufacture of a kind of gin, known as *Hollands* or *Geneva*.

The vast quantities of spirits which are manufactured in the British Islands require a more complicated form of still than the simple apparatus already described, fig. 137. The process of rectification is costly: so that it was long considered a desideratum to complete the process of distillation and rectification in one operation. This was done by means of a still invented by a Frenchman, named Adam. The principle of his invention consists in connecting together a number of rectifying chambers, in such a manner that the vapour given off by the chamber nearest the fire shall condense in a second chamber, and by the heat due to its condensation cause the more volatile portions of the liquid in this second chamber to distil into a third chamber, while the vapours of the third chamber shall condense into a fourth, and so on, until the required degree of concentration is produced. This plan is carried out in the still used in this country, known as *Coffey's still*, a section of which is represented in fig. 147. *BB* is the body, made of copper, and enclosed in a case of wood to preserve the heat. Rising from the body are two columns, *TF*, *HK*, while *O* is the vessel from which the liquor to be distilled is raised by means of a pump *LL;* the liquor enters the column *HK*, by the long spiral pipe *LL*, by which it is conveyed through the pipe *M*, in the direction of the arrows to the top of the column *TF*. The heat used for distilling is furnished by means of steam, which enters the body through the pipe *A*, the amount of which is regulated by a valve *F*. The body *BB*, is divided into two chambers, by means of a copper shelf pierced with small holes, which allow the steam to pass upwards, but are too small to prevent much of the liquid from passing down through the shelf. The steam soon raises the liquid in *B* to the boiling point, first driving off the more volatile alcoholic portions. This vapour traverses the liquid in *B*, raises it to the boiling point, and vaporizes the alcohol; which vapour passes off by a pipe *Z*, to the bottom of the bottom *TF*. This column is divided into compartments by means of perforated copper shelves, and each shelf is furnished with a pipe for conveying the liquid to the shelf below. Each pipe projects about an inch above the upper surface of the shelf, so that about an inch depth of liquor is retained upon each shelf, and is traversed by the vapours which ascend from the shelf next below it. The wash having become heated in its passage through the spiral pipe in *HK*, falls upon the top perforated shelf in *TF*, flows off at the further end of that shelf, and then falls upon the next shelf, from which it passes to the third, and so on to the other shelves; meeting, as it descends, the ascending vapours, which gradually become more and more alcoholic, while the wash, as it descends, becomes weaker and weaker; until, at length, when it arrives at the body *BB*, it is wholly deprived of spirit. The shelves are also furnished with valves *TT*, to allow the ascending vapour to pass, should the perforations in the shelves not afford sufficient space. When the vapour has reached the top of the column *TF*, it is conveyed by means of the steam-pipe *TTN*, to the bottom of the finishing column or rectifier *HK*. The lower part of this column, as high as the pipe *Y*, is constructed on the same plan as the column *TF;* but in each compartment, between the shelves, the spiral pipe *LL* makes three or four turns, whereby it becomes warmed by the hot ascending vapours. In this second column, the alcoholic fluid distilled over from the first column undergoes rectification on each of the lower shelves, and becomes more and more concentrated by the ascent of the alcoholic vapours; which by being condensed at each successive stage, give out heat enough to distil the more volatile portions of the liquid by which they are condensed. The five upper shelves of this column merely act as a condenser for the alcoholic vapours: these shelves are not perforated, but are attached alternately to the sides of the column, so as to leave a narrow passage at one end of each shelf, and thus force the vapours to take a zigzag direction. The pipe *Y* carries off the finished spirit, while the pipe *R* conveys any uncondensed spirituous vapour to a refrigeratory, and the weak spirit which reaches the lower part of the column is returned to the vessel *O*. The spent wash, as it accumulates in *BB*, is drawn off from time to time, so that the still can be worked without interruption. One of these stills at Inverkeithing distils 2,000 gallons of wash per hour, and there is one at least, which distils upwards of 3,000 per hour. Some of the store vats (fig. 146) rival those of the London porter brewers (fig 133); 20,000 gallons of whisky being sometimes stored in one vat. In some cases, water is distilled as well as alcohol, so that the latter is reduced to the proper strength by a suitable dilution supplied by the former.

The manufacture of spirits yields large returns to the revenue of the country, so that it is carefully watched by the officers of excise to prevent illicit distillation. In the year 1858, there were retained for consumption in the United Kingdom 10,028,591 gallons of spirits; in addition to which, 1,686,236 gallons were exported. In the year 1857, the total amount of excise duty collected in Great Britain and Ireland was no less a sum than 9,132,601*l.* The duty is 8*s.* per gallon. Attempts have been made to diminish the consumption by imposing a high duty on the spirits, but these have always turned out to be failures; for where the poorer classes have been unable to purchase high-priced drinks, the smuggler and the illicit distiller have always been ready with their untaxed spirits to supply the demand. The only safeguard for the poor against drunkenness is to be found in the active influence of the educated classes in pointing out the dreadful effects of this vice, in distributing books, in promoting parochial visitations, in opening churches to the parents and schools to their children; these are some of the measures which we may hope will, under the Divine blessing, tend to diminish a vice which is so extensive as to be a national curse.

VII.—THE BRICKMAKER.

"Let us make brick and burn them throughly," was the saying of the builders of the tower of Babel. (Gen. xi. 3.) This and many other proofs exist of the antiquity of brick-making, and of the employment of bricks in the earliest structures. Several of the pyramids of Egypt are built of bricks, and the walls of the most ancient cities were constructed from the clay dug out of their trenches and made into bricks. The Romans made great use of brick, and first introduced it, apparently, into our island. But it was not a favourite material with our people. Down to the time of the Great Fire of London, ordinary houses were made of a framework of timber, filled in with lath and plaster, or with panels of brick; and it was only after that fearful event that the great use of timber was discontinued, and brick became the prevalent material. Bricks, when well made, form perhaps the most durable of all building materials; but English bricks of the present day are inferior to many that are made abroad, especially in Holland, where the art has been brought to great perfection. Our materials are good, but the mania for cheapness which exists in this country, and which is fostered by the metropolitan system of granting land on building leases, on the expiration of which the houses become the property of the landlord, tends constantly to encourage contrivances for saving labour and fuel, to the injury of the bricks.

Various argillaceous earths are employed in brick-making, but they are generally unfit for use without a greater or less admixture of some other substance. The purer the clay, the more likely is it to split in drying; and on the other hand, the lighter, looser, and more sandy the clay or loam, the more needful is a material to bind it into a compact mass. Bricks for common purposes are known as "place-bricks," "gray and red stocks," "marl-facing bricks," and "cutting bricks." The first two kinds are ordinary wall bricks, the "marls" are of superior quality for facing the outsides of houses, and the finest marls and red bricks are called cutting bricks, from their being used in arches, over doors, &c. and rubbed to a centre or gauged to a height. Certain foreign hard-baked bricks, called "Dutch" and "Flemish" bricks, and clinkers, are used for paving stable-yards, lining ovens, &c. Ventilating bricks and hollow bricks are now extensively made. They are larger and lighter than ordinary bricks, and take less material.

Whatever the variety of brick to be made, the clay must go through a long preparatory process. It is dug up in the autumn and left exposed to the mellowing influences of frost, snow, and rain. Frequently during the winter also, the masses are broken up and turned, so that the atmosphere may penetrate them in every direction. In the spring, the clay thus broken up is thrown into shallow pits, where it is soaked with water and tempered. But for the superior bricks used for the outside of houses, the plan is different. The clay, in this case, is ground to pulp in a *wash-mill* (fig. 148) as soon as it is dug in autumn, and is mixed with chalk previously ground and made into a creamy liquid with water. The mixture thus formed is allowed to run off through gratings, and settle until it is firm enough for a man to walk upon; it is then covered with finely sifted ashes, and left all the winter to mellow. In the spring, the clay is dug up with pick and shovel (figs. 156, 158) and the ashes are thoroughly mixed with the clay, and pugged in a *pug-mill* (fig. 149). This is a conical wooden tub, with a vertical revolving shaft passing through it. On this shaft are placed a number of knives, which cut and knead the clay, and force it through the mill, which is filled at the top from the barrows of the work-people (fig. 153), and has a hole at the bottom where the clay issues forth and is cut into pieces and piled up for use. Where the demand for bricks is large, the pug-mill is indispensable, but in many country places the kneading and tempering of the clay is still performed by the naked feet of the labourers, which, from long practice, become sensitive to the presence of the smallest stone or roughness which interferes with the uniform texture of the mass.

The clay, being by this means brought into the necessary state for brickmaking, is next conveyed to an open shed in the brick-field (fig. 157), where the moulder, with an assistant, stands at his bench, rapidly converting the plastic material into bricks. At such a bench the writer often used to stand for hours, as a child, watching the moulder, and receiving gracious permission occasionally to help in the work, the practical details of which became thus perfectly familiar. On the moulder's bench were placed a trough of water, a heap of sand, a pile of boards called *pallets* (fig. 154), and a *mould* (fig. 152). Floating on the surface of the water was a *strike* (fig. 151), which, in our case, was only a smooth strip of wood rounded at the ends, without the opening for the hand shown in the figure. Fixed to a convenient part of the bench, was a board exactly the length and breadth of the intended brick; this was called the *stock-board* (fig. 150). The first thing the moulder did, was to take up the mould (fig. 152), a frame without top or bottom (now generally made of brass, but in former days of wood), and dash it into the heap of sand, so that it might be well sanded inside and out. He then placed it on the stock-board, which it fitted exactly, and yet so easily as to give no trouble in adjustment, and slapped into it a mass of clay, rather more than enough to fill it; pressing down the mass so that it might fill every portion of the mould, there still remained an overplus, which was rapidly shaved off by the strike, or wet piece of wood close at hand, which was taken out of the trough for the purpose, and returned to it again almost in an instant. One of the pallets was then taken from the pile, dashed into the sand-heap, and laid on the top of the new-made brick in the mould. The mould was turned over, and the brick thus transferred to the pallet was ready to be carried away on the *hack-barrow* (fig. 155). The pallets are of the same width as the mould, but a little longer; six-and-twenty pallets form a set, and three sets are required by each moulder. The hack-barrow has a flat top of light framework, fit to receive two rows of bricks, thirteen in each row. Three of these barrows are kept in constant use by one moulder. One barrow stands at his side and is rapidly filled as he makes the bricks, another is

unloading in the drying-ground, and the third is being wheeled back from the drying-ground, to take the place of that which is being filled. In the drying-ground, a succession of long, level, well-sanded paths of earth, a little raised above the rest of the field, afford space for the bricks, which are built up in *hacks* or low walls, two bricks wide and eight bricks high, with spaces between for the passage of currents of air. The bricks are placed at first in a single layer the whole length of two of these paths, so that by the time the end of the second is reached, the first is firm enough to allow of a second layer of bricks. The hacks are protected with straw or hay, or a thatched frame (fig. 161) at night and in bad weather. In some cases, drying under cover is adopted for very superior bricks, and flues are carried under the floor of the drying sheds to hasten the process. The outer air is then carefully excluded.

Rapid as are the movements of the brickmakers, they are not quick enough to meet the enormous demand for bricks of the present day. Machines have been contrived for moulding bricks, and these far outstrip human hands in speed, but do not produce equally successful results. Machine-made bricks are very smooth, dense, and heavy, but they do not adhere to the mortar so well as others, and their weight increases expense in carriage, and prevents the workman from laying so many in a given time. It is a very common practice at the present day to diminish the weight of bricks by hollowing them out beneath, and thus also leaving a bed for the mortar. In order to make these hollow bricks, it is only necessary to fix on the stock-board what is called a *kick* (fig. 150), which is a piece of wood elevated in the centre, and thus taking up some of the room in the mould which would otherwise be filled with clay. But there is another kind of hollow, or perforated brick, in which little tunnels are driven through the brick longitudinally, in the same manner and by the same kind of machine as in the drain-pipes used in agriculture (fig. 160). These bricks, from their mode of manufacture, are more compressed than ordinary bricks; they are also of larger size, so that nine hollow bricks will do as much walling as sixteen of the common sort, with only a slight increase in weight (fig. 159). Altogether, the advantage of the patent bonded hollow bricks over others is stated to amount to twenty-nine per cent., in addition to a considerable diminution in the cost of carriage or transport, and of twenty-five per cent. on the mortar and labour.

But our notice of the brick manufacture has only as yet conveyed the new-made bricks to the drying-ground. When sufficiently hardened, they are taken thence to the kiln, or *clamp*, to be burned. The kiln is the older and the better plan. It is usually a simple rectangular chamber, built of old bricks and rubble-stone, with a narrow doorway at each end, and fire-holes lined with fire-bricks at each side exactly opposite to each other. The workmen carry in at the doorways a quantity of bricks piled up on the barrow (fig. 162), and stack them loosely, but with considerable art, in cross-courses, from wall to wall, leaving openings that shall act as flues, and distribute the heat from top to bottom. When the kiln is thus filled with bricks, to the number of about 20,000, the top is covered in, and fires are lighted in the fire-holes. The heat is kept moderate for the first two or three days, that the remaining moisture of the bricks may be gradually evaporated; but when the steam ceases to rise, the heat is raised, the doorways are bricked up, and the temperature continued till the fire begins to appear at the top, when it is slackened, and the kiln allowed to cool. The heating and cooling are then repeated, and in about forty-eight hours the bricks are thoroughly burnt. The kiln is heated with furze, heath, brake, &c., or with pit-coal, as the case may be. The burning of bricks in a clamp is a much slower process—it occupies from two to six weeks; and the bricks in some measure supply their own fuel from the quantity of ashes (technically called *breeze*) employed in their manufacture. Layers of ashes are also added, as the bricks are built up into a central double wall, with other walls of brick on each side leaning against it, the whole being framed with considerable skill into an immense mass, or clamp, the sides and top of which are cased with burnt bricks, while numerous *live-holes* are left, which are fired in succession, the fuel being wood, coal, and breeze. The bricks are not in this manner equally fired, the outer ones being not burnt enough, while those near the fire-holes are burnt too much, and frequently run together in masses and are spoiled. Specimens of this fused brick may frequently be seen in the rock-work of suburban gardens.

Such is an outline of the process of brick-making, but there are variations in different parts of the country. Sometimes the clay is ground between rollers, instead of being passed through the pug-mill; sometimes the wash-mill only is used. The processes of moulding and drying are also far from uniform, and the form of the kiln is subject also to variation.

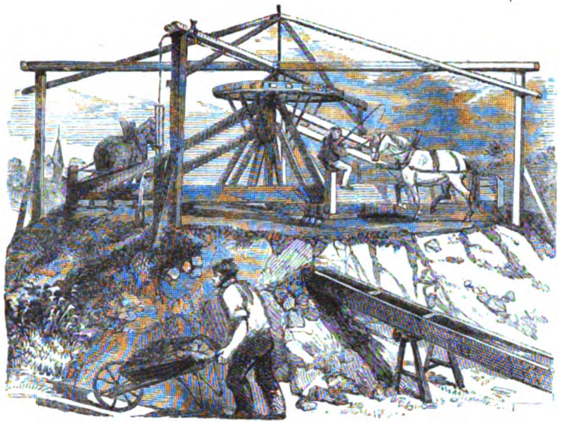
A method has been devised by Mr. Prosser, of Birmingham, of making ornamental bricks, floor-tiles, &c. of clay, nearly in the state of a dry powder. A strong pressure is given by machinery to the clay in metal moulds. This pressure reduces it to one-third its original thickness, and gives it sufficient compactness to be handled at once and taken to the drying-kiln.

The manufacture of ordinary tiles, whether for covering the roofs of houses or for paving, is conducted on the same general plan as that of bricks: indeed, they may be considered as thin bricks. The mould is shallower, the stock-board is of a different shape, and the drying is performed on shelves of plank under a shed, instead of on the ground. Drain-tiles are made by machinery, which cannot be here described.

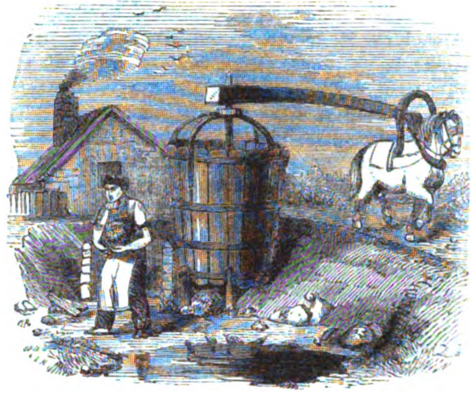
VIII.—THE BRICKLAYER.

THE bricklayer was never more active than at the present time. The vast increase of houses in the neighbourhood of London is a convincing proof of the prosperous state of his trade. In the country, also, similar signs of activity are in many directions to be observed, and we can only hope that the mania for cheap and rapid building may not be indulged, to the cost of the owners and occupiers of such houses. Bricklaying of the best and of the worst description may be seen in London; houses of careful and solid construction, raised on secure and good foundations, and houses hastily built of bad materials, on no foundation at all. From the very nature of brick walls, it is obvious that a safe and secure foundation is of the utmost importance. Trenches should be dug, and the ground be carefully examined, to ascertain its soundness. The looser parts of the soil should be dug up until the solid bed is reached, and the ground should be made good by ramming in large stones closely packed together, or by the use of concrete.

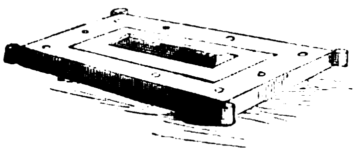
Ordinary English bricks are usually of one form, nine inches long, four inches and a half broad, and two inches and a half deep. Their quality depends entirely on the materials of which they are made, the method in which the clay is tempered, and the manner of burning. The lime used for mortar is slacked in small quantities, and covered with finely sifted sand to exclude the air (fig. 174). When used, it is beaten three or four times, and turned over with a beater, so as to incorporate the lime and sand, and a little more water is then added. In hot and dry weather the mortar is made much softer than in winter: the bricks also are wetted before they are laid, otherwise in dry seasons they fail to adhere to the mortar. The building of a wall must be gradual, for the work will always shrink, and time



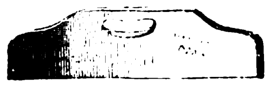
148. WASH MILL.



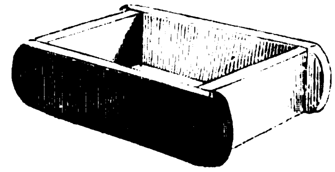
149. PUG MILL.



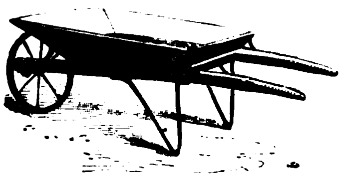
150. KICK AND STOCKBOARD.



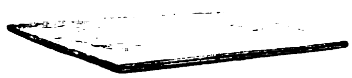
151. STRIKE.



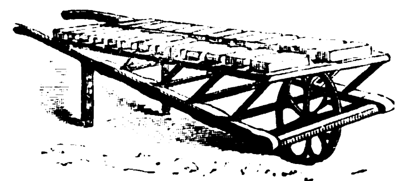
152. MOULD.



153. BARROW.

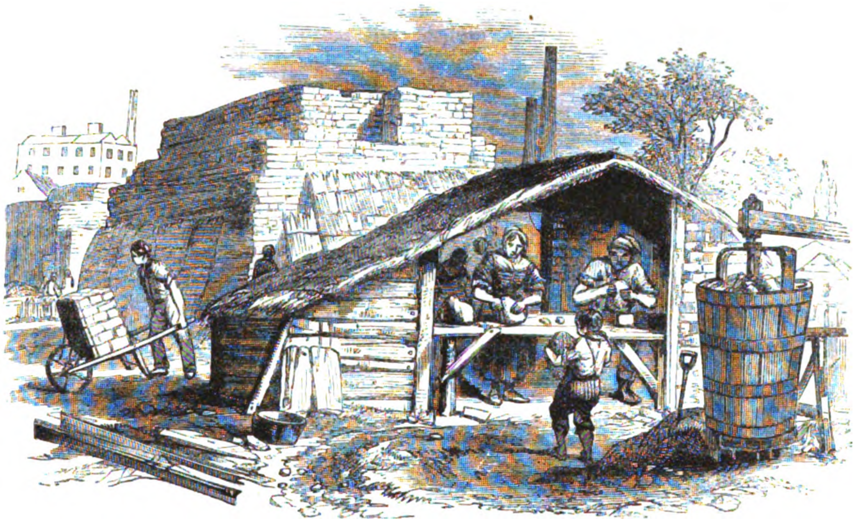


154. PALLET.

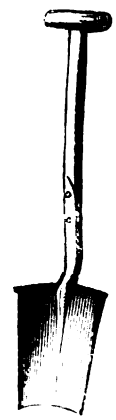


155. HACK BARROW.

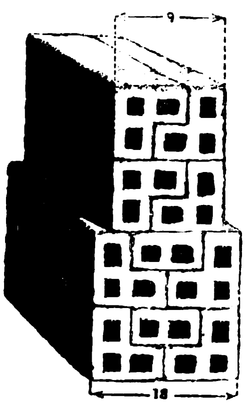
156. PICK.



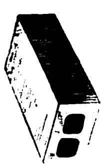
157. BRICKFIELD, MOULDER'S BENCH, KILN, &c.



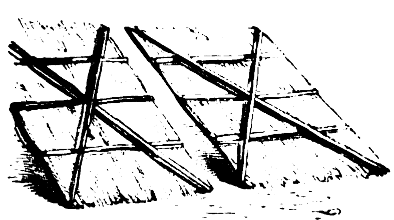
158. SHOVEL.



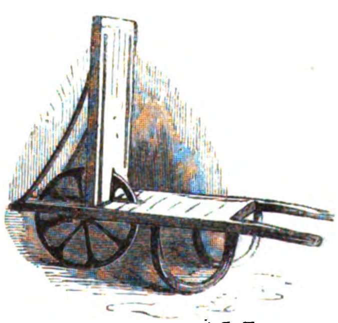
159. METHOD OF LAYING HOLLOW BRICKS.



160. HOLLOW BRICK.



161. REED FLATS.

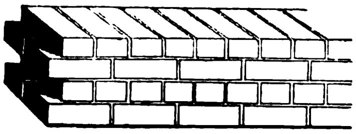


162. BARROW FOR CARRYING BAKED BRICKS.

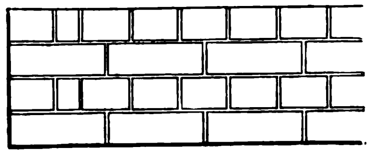
must be allowed for it to do so equally. Four or five feet at any one part is as much as is usually built at one time. The strength of the wall (supposing the foundation to be good) depends on the manner in which the bricks are laid. There are two methods, in one or the other of which nearly all English brickwork is executed. The first is called *Old English bond*, and the bricks are laid in the manner shown in fig. 163. The first layer is formed with bricks laid lengthwise, and this forms what is called a *stretching-course*, and the separate bricks are called *stretchers;* the second course is formed with bricks laid crosswise, and this is called a *heading-course*, and the separate bricks *headers*. Flemish bond was introduced into England about the reign of William and Mary, and is formed by placing stretchers and headers alternately in the same course (fig. 165). This is thought to produce a more pleasing effect externally, but does not form so strong a wall. The perpendicular face of a wall built in Old English bond, and another built in Flemish bond, are shown at figs. 164, 166. In English bond it is a fundamental rule, that every brick in the same course must be laid in the same direction, but that no brick shall be placed with its whole length alongside of another; but be so situated, that the end of one may reach to the middle of the others which lie contiguous to it, except at the end of the course, where, to prevent a continued upright joint in the face-work, three-quarter bricks are necessarily used. This rule shows at once a source of superiority over Flemish bond, where it is impossible to adopt it, and where the walls are consequently weaker. In fact, the frequent splitting of walls done in Flemish bond has led to the practice of putting laths, or slips of hoop iron, in the horizontal joints between the courses. A careful adjustment of bricks is required in turning the corners of a wall, as that is the part where a house is most liable to split. If you call in your landlord, and inform him that you have noticed signs of weakness in your house, that you feel the vibration of passing vehicles too acutely, and that you hear sundry cracking sounds in various parts of the building in dry weather, he immediately walks to the corners of the room and examines their condition. If the papering or the paint be not defaced, if no crack or appearance of giving way is there visible, and if all the rooms of the house are in a similar condition, he assures you that you may feel perfectly secure. Knowing as he does that the foundation is good, he is very well aware that no serious mischief can happen to the house, without some such signs of weakness at the corners of the building. The corners of a wall laid in English bond are much after the manner shown in figs. 167, 168. Fig. 168 represents a two-brick wall, where every alternate header in the heading-course is only half a brick thick on both sides; which breaks the joints in the core of the wall, and where the arrangement for securing strength to the corner is also shown. Fig. 167 represents the mode of working English bond in a fourteen inch or brick and a half wall, in which the stretching-course upon one side is laid, so that the middle of the breadth of the bricks on the opposite side falls alternately upon the middle of the stretchers and upon the joints between the stretchers. It is usual to let the bricks of a wall incline slightly towards the centre, that one half of the wall may be in a measure a support to the other half. Unfinished walls must be carefully preserved from the effects of rain and frost, by straw and wooden coping. Were rain to penetrate the wall, and frost to convert the water into ice, the expansion in freezing would burst the wall, and crumble the materials of which it is composed. After a wall is built, the joints of the bricks on the outside are often filled up with mortar, so as to present a regular and neat appearance. In order to do this effectually, the mortar already in the joints is raked out to a certain depth, and filled up again with blue mortar. This filling up is called *pointing;* if the courses are simply marked with the edge of the trowel, it is called *flat-joint pointing;* if, in addition to this, plaster be inserted in the joints, and neatly pared and finished, it is called *tuck-pointing* or *tuck-joint pointing*.

In all these works, the bricklayer needs but few and simple tools. In the first place, he must have a *brick-trowel*, of which two shapes are shown at figs. 169, 170. These are for taking up and spreading the mortar, and pressing it into crevices, and also for cutting bricks by percussion to any required size. Holding a brick in one hand, and giving it a smart blow or two with the edge of the trowel, the workman easily divides the brittle material at the desired part, while he also makes that ringing sound which proclaims all over the neighbourhood that building is going on. Next, he must have a *hammer* (fig. 171), one end of which does similar service in dividing bricks and making holes in brick-work, being for that purpose shaped like an axe. The *plumb-rule* (fig. 176) is necessary to enable him to carry up his walls perpendicularly: it is a thin rule, six or seven inches wide, with a line and plummet hanging in the middle; while this enables him to keep the perpendicular, the *level*, with its line and pins (fig. 179), assists him in preserving the horizontal level. He may often be seen trying with this instrument (which is ten or twelve feet long, and which has a vertical rule attached to it, in which the line and plummet swing,) the levels of the walls at various stages of the building, especially at the window-sills and wall-plates. He will also need a *square* (fig. 172), for setting out the sides of a building at right angles; a *jointer* (fig. 173), which is used with a rule for marking the joints, and is an iron tool shaped like the letter S; and a *raker* (fig. 175), a piece of iron with sharp points, for raking out mortar from the joints of a house when it is being pointed. Another implement, as characteristic of a bricklayer as it is necessary to his work, is a *hod* (fig. 181). This is a wooden trough, closed at one end and open at the other. The sides of this trough consist of two boards at right angles to each other, having a long handle fixed to the middle of the ridge. On this ridge is also a cushion of leather, stuffed with wool, to prevent it from cutting the labourer's shoulder, as he rests it there in conveying it, laden with bricks or mortar, to the spot where the bricklayer is at work. The hod is duly sanded, to prevent the mortar from sticking to it; and it is often so heavily laden, that the task of carrying it up ladders, or across portions of the building or scaffolding where the footing is precarious, is no easy matter. For the preparation and cutting of gauged arches of brickwork, the *brick-axe*, or *cutting-chisel* (fig. 177), is employed for axing off the soffits of bricks. For the coarser works connected with the foundation, and with the preparation of materials, the *pickaxe*, the *shovel* (fig. 180), the *crowbar* (fig. 182), and the *mortar-rake* (fig. 183), are all necessary. The cutting of bricks for nice or ornamental work requires a *bench* and a *cutting-block*, and several additional tools, such as the *camber-slip*, a long slip of wood with a curved edge, rising about one inch in six feet; a *rubbing-stone* fixed to the bench, for rubbing down bricks which have been roughly shaped for gauged work; the *bedding-stone*, a piece of marble for trying the rubbed side of a brick, to ascertain that it is straight; a *bevel*, for drawing the soffit line on the face of the bricks; the *mould*, for forming the face and back of the brick, in order to reduce it in thickness to its proper taper; the *scribe*, a spike or nail, to mark the bricks; a *tin saw*, for cutting soffit lines one-eighth of an inch deep; the *templet*, used for taking the length of the stretcher and width of the header; and the *float-stone*, for rubbing curved work smooth, and to take out the marks of the axe.

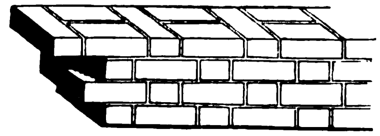
Brickwork is estimated by its measurement in *rods*. A rod of brickwork consists of 272 superficial feet. The standard thickness of a brick wall is one brick and a half, or 13½ inches; so that, if 272 square feet be measured by 13½ inches, the result will be 306 cubic feet in the rod. A rod of standard brickwork with mortar will require about 4,500 bricks, allowing for waste. The mortar contained in a rod of brickwork consumes 1½ cwt. of chalk lime, or 1 cwt. of stone lime, and 2½ loads of sand with stone lime, or 2 loads with chalk lime. The weight of a rod of brick, containing 4,500 stock bricks, 27 bushels of chalk lime, and 3 single loads of drift sand, is about 13 tons. In common walling, where there are few or no interruptions in the way of



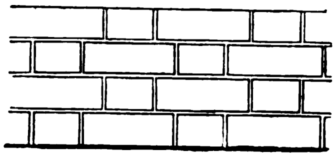
163. ENGLISH BOND.



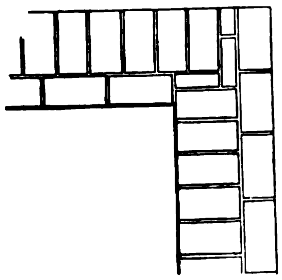
164. ENGLISH BOND. (*Elevation.*)



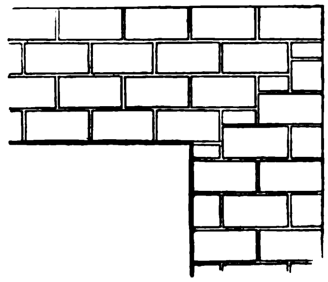
165. FLEMISH BOND. (*Elevation.*)



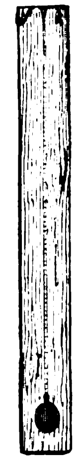
166. FLEMISH BOND. (*Elevation.*)



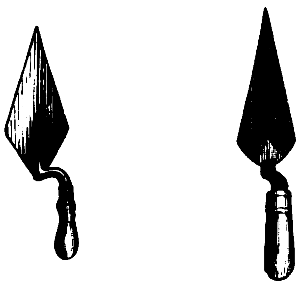
167. BRICK AND A HALF WALL. (*Plan.*)



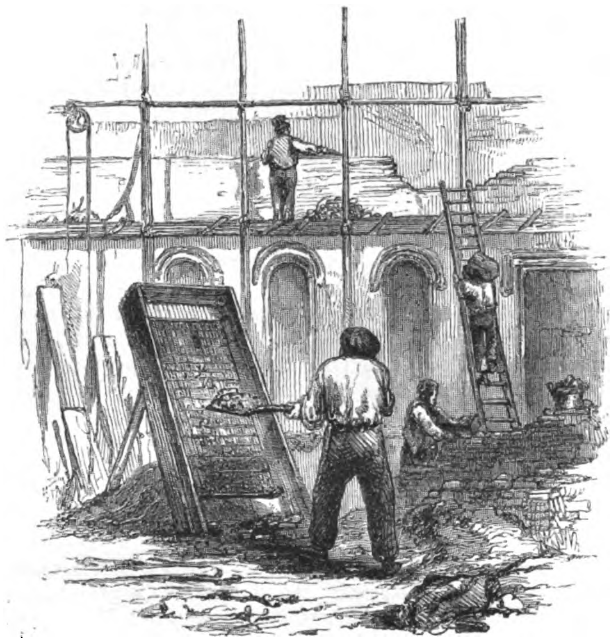
168. TWO-BRICK WALL. (*Plan.*)



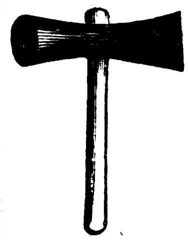
176. LINE AND PLUMB.



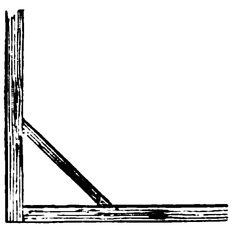
169, 170. TROWELS.



174. SCREENING SAND AND BRICKLAYING.

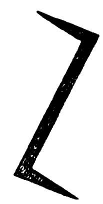


171. BRICK HAMMER.

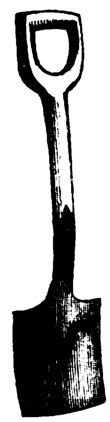


172. SQUARE.

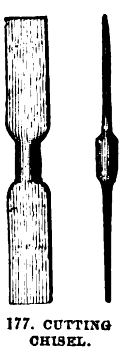
173. JOINTER.



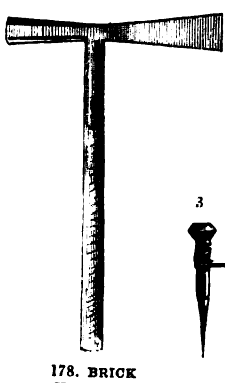
175. RAKER.



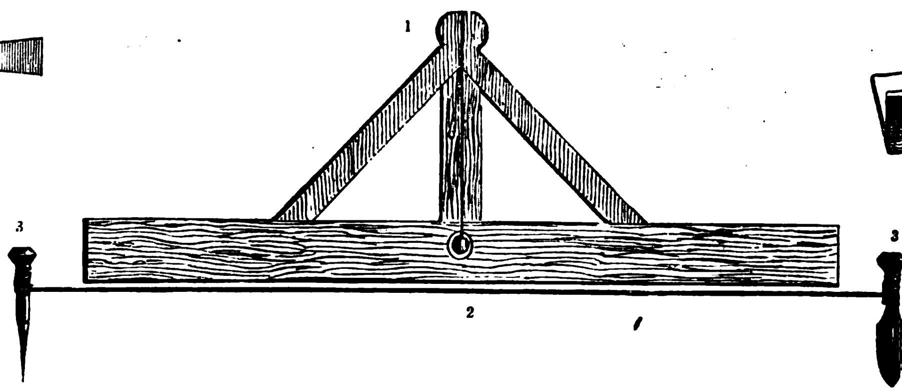
180. SHOVEL.



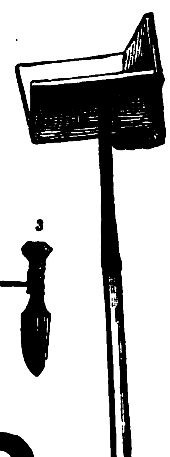
177. CUTTING CHISEL.



178. BRICK HAMMER.



179. 1. LEVEL. 2. LINE. 3. PINS.



181. HOD.

182. CROWBAR.

183. MORTAR RAKE.

recesses, &c., one bricklayer will lay 1,000 bricks each day, or complete a rod in about four days and a half. One labourer is assigned to each bricklayer, when the work is easily reached; but when the building has risen to some height, and time is lost in mounting ladders, &c., a second becomes necessary. The labourer is paid at the rate of two-thirds of the bricklayer's wages per day. Under ordinary precautions, this need not be an injurious or a dangerous trade; yet we seldom hear of the erection of any extensive structure without some casualty to the work-people employed. The fact is, that from long habit, they grow insensible to danger, and do not exercise the common caution which any man in his senses might be supposed to use under the circumstances. Great blame also rests on those who have the management of scaffolding, if they neglect to make it strong enough for the weight it will have to sustain, and for the number of work-people required on the structure.

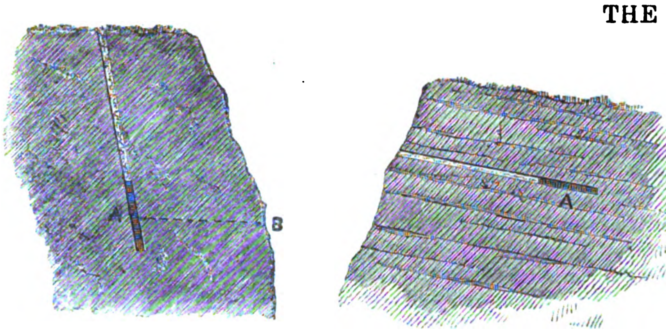
IX.—THE MASON.

The various stones used in building are got out of the earth or separated from the rocks by the quarryman. The excavation from which the stone is got out is called a *quarry*, from the circumstance that the stones are squared or quadrated (*quarré*), or formed into rectangular blocks. In order to separate a block of stone from the rock, the quarryman bores a hole by means of a *borer*, or *jumping tool*, which consists of a heavy iron rod, something like a crowbar, which is lifted up and allowed to fall by its own weight, or it may be struck by means of a hammer, the jumper being turned after each stroke, so as to have a fresh portion of rock presented to its chisel edge after every blow. In this way a hole is formed, and every now and then the jumper is taken out, and the hole is cleared of chips by means of a scraper. When the hole is sufficiently deep, a quantity of gunpowder is poured into it; a long needle is then inserted into the hole and partly into the gunpowder, after which a little wadding of hay is put in over the powder, and the hole is filled up with broken brick or pounded stone, called *tamping*, which is rammed in by means of an iron rod, or tamping bar. The last inch or two of the hole is filled up with damp clay. The needle is then carefully pulled out, and the narrow opening left by it is filled up with gunpowder, or with straws filled with gunpowder, and into the upper end of the top straw is inserted a piece of touchpaper, sufficient to burn for half a minute: this is lighted; the men retire to a distance, and the touchpaper fires the train, and the charge and the explosion detaches a large mass of rock. The touchpaper is made by soaking coarse paper in a strong solution of saltpetre and drying it; but it is better to fire the charge by means of a *fuse*, which consists of a quantity of gunpowder enclosed within a hempen cord, and which burns or smoulders slowly. Fig. 184 shows the hole filled with this charge of gunpowder and tamping. When the charge is fired, it will break off a portion of the rock in the direction of the line A B. In stratified rocks, the hole is usually bored in the direction of the joints or seams, as in fig. 185, where the powder at A may be introduced in the form of a cartridge, and this will have more effect in lifting large masses than if placed across the grain. The blocks are roughly brought to shape by means of the stone-axe (fig. 191), or the point (fig. 202).

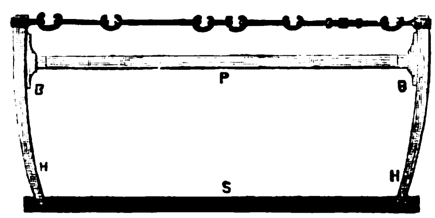
The tools employed by the mason vary in different places, according to the quality of the stone. In London, where stone is scarce, it is cut into scantlings by means of a saw (fig. 186). The saw *S*, is from five to ten feet in length, and from one-sixth to one-eighth of an inch in thickness; it is fastened to the upright side of a frame *H*, at each end by an iron pin, and is kept distended by a wooden stretcher *P*, called the *pole*, placed near the top of the frame, while the upper ends of the frame are drawn together by means of a chain, to which tension is given by a double screw. The lower end of the frame serves as a handle, by which the saw is made to work forwards and backwards. The stone-cutter is represented at work in fig. 195: at the top of the block is a small barrel of water, resting on an inclined plane; the latter is covered with a sharp cutting sand, which trickles down into the cut with the water, and greatly assists in cutting the stone. The workman has near him a long stick furnished with an iron hook, called the *drip-stick*, with which from time to time he brings the sand into the path of the water. The saw-frame, which is very heavy, is usually counterpoised by means of a weight attached to a cord, and passing over a pulley so as to reduce the pressure, and lighten the load. The tall pole, seen in fig. 195, carries this weight. In this way a block of stone is with much labour cut up into a number of slabs. Sawing machines have been introduced, in which a frame containing eight or ten saws, moved by machinery, cuts up a block of stone in a comparatively short time. The slabs thus formed sometimes require to be cut into smaller slabs. When this is done by hand, a *grub-saw* (fig. 189) is used. This is a plate of iron clamped at the upper edge between two pieces of wood, to serve as a handle, and the cut is made with the assistance of water and sand, as before. This operation is also performed by machinery in what is called a *ripping-bed*, in which a number of circular saws, mounted on the same axis, perform the work very quickly. Slabs are smoothed by means of rubbers attached to the long rod (fig. 198*), consisting of coarse cloth, which are moved backwards and forwards over the slab by hand, the polishing material being sand of various degrees of fineness, and afterwards emery and putty-powder for finishing. The polishing of marble, &c. is also performed by machinery in what is called a *polishing bed*.

In places where stone is abundant, it is divided into smaller scantlings by means of wedges (fig. 196). Hard stone and marble are brought to a surface by means of a *mallet* (fig. 187) and *chisel* (figs. 192, 193). The tools used in London for hewing stones are of iron tipped with steel, and the cutting edge is the vertical angle. The mason also uses a *level*, a *plumb rule*, a *square*, a *bevel-square*, a *straight edge* (fig. 194), and various other *rules* for trying surfaces as the work proceeds. In working the face of a stone, the tools are the *point* (fig. 190), the *inch tool*, the *boaster*, and the *broad tool*. The operation of working with a point is called *pointing*, and that with the boaster, *boasting*. The action of the point is to leave the surface in narrow furrows, with rough ridges between them. The inch tool is used in cutting away the ridges, and the boaster in making the surface nearly smooth. The boaster is about 2 inches wide, and the broad tool $3\frac{1}{2}$ inches at the cutting edge. In working with the broad tool a series of cavities are produced following one another in a straight line, and the whole surface of the stone is gone over in the same manner, producing a number of equidistant parallel lines. This method of hewing is called *stroaking*. In another operation, which is called *tooling*, every successive cavity is repeated in new equidistant lines over the length or breadth of the stone, when a new series of cavities is repeated until the whole of the stone has been gone over. There are also various tools for working cylindrical and conical parts of mouldings.

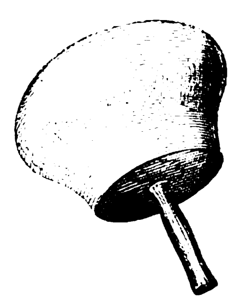
In the erection of a stone building, the stones are placed in position by means of a contrivance called the *lewis* (fig. 197). This consists of three pieces of iron, *a c b*, with holes at the top for the insertion of a bolt *b'*, *b''*, and a ring *r*. A hole is cut in the middle of the upper surface of the stone about 7 inches in depth, and about 1 inch wider at the bottom than at the top. The pieces *a b* being first introduced into the hole, the piece *c* is driven in, the ring *r* is put in its place, and the bolt is passed through all five holes. It is evident that the instrument must hold the stone



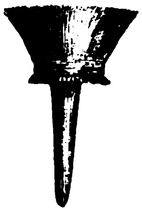
184, 185. METHOD OF BLASTING ROCKS.



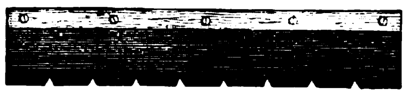
186. MASON'S SAW.



187. MALLET.

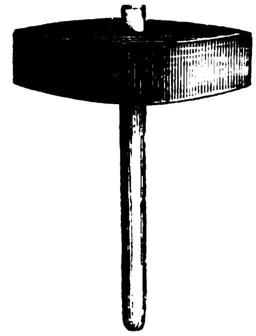


188. WASHING BRUSH.

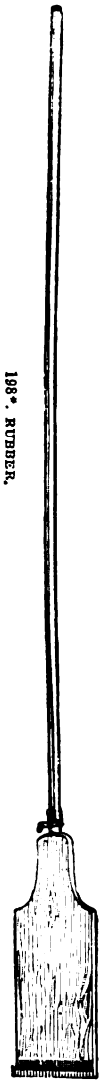


189. HAND OR GRUB SAW.

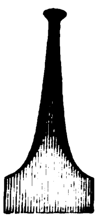
190. POINT.



191. STONE AXE.



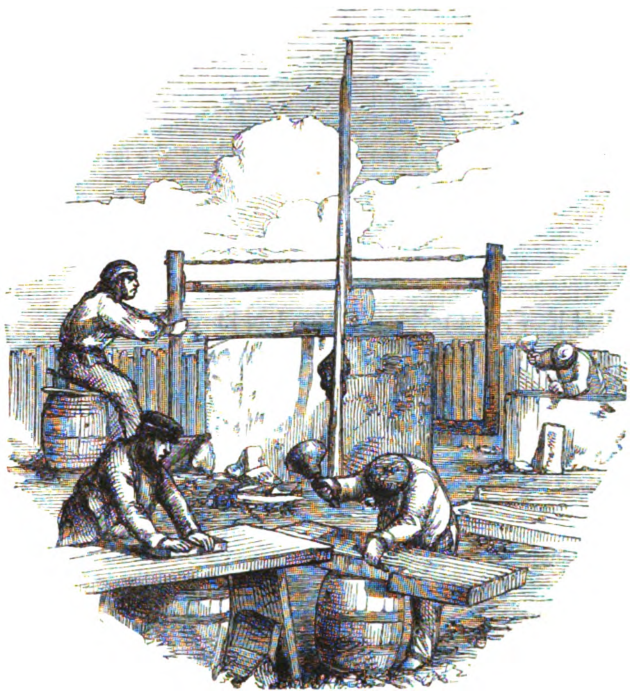
198*. RUBBER.



192. CHISEL.

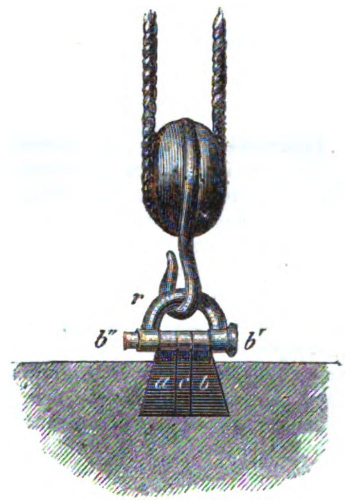
194. STRAIGHT EDGE.

193. CHISEL.



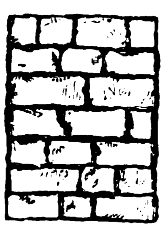
195. MASONS AT WORK.

196. WEDGE.

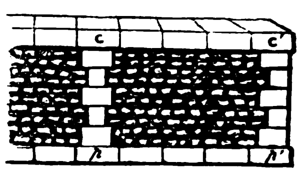


197. THE LEWIS.

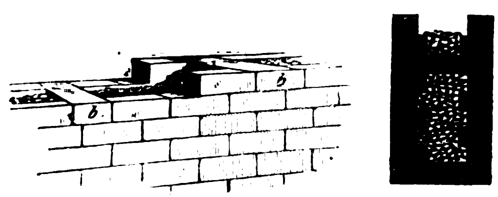
198. RUBBLE WORK.



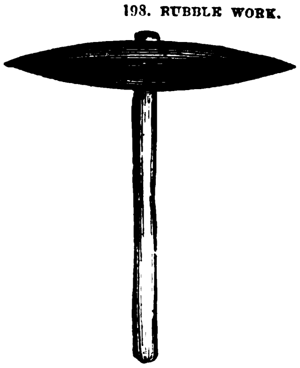
199. COURSED WORK.



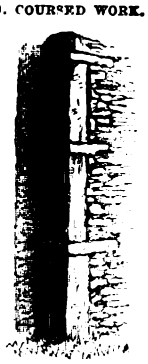
200. SUPERIOR RUBBLE.



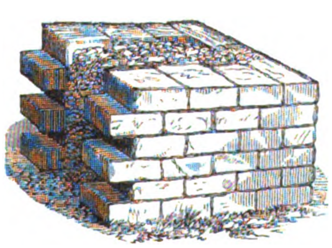
201. WALL WITH HEADING OR BOND STONES.



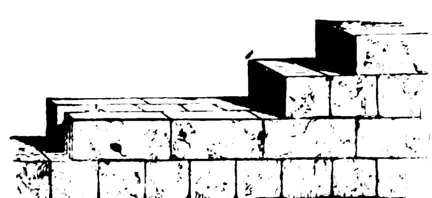
202. PECK OR POINT.



203 LONG AND SHORT WORK.



204. ROMAN EMPLECTUM.



205. ITALIAN.

securely and allow it to be raised on a pulley, as shown in the figure. The lewis is said to have been invented by a French mechanic employed on the works of Louis XIV., and named in honour of that monarch. The examination, however, of ancient ruins shows that the lewis was known many centuries ago. In the year 1762 a portion of Whitby Abbey was blown down during a storm, when some of the stones, weighing nearly $1\frac{1}{2}$ tons each, were found to have a cavity in them similar to that which is now cut for the reception of the lewis. Whitby Abbey was rebuilt in the reign of William Rufus.

Various kinds of masonry are practised, and they may be ranged under three heads; *first, rubble-work* (fig. 198), in which the stones are used without being squared; *second, coursed work* (fig. 199), in which the stones are squared, more or less sorted into sizes and ranged into courses; *third, ashlar work*, in which each stone is squared and dressed to given dimensions. The thin facing of stone sometimes placed in front of brick work is also called ashlar. The rubble wall is often improved in appearance and solidity by the introduction of cut stone as in fig. 200, in which *c* is the *coping*, *p* the *plinth*, *o' p'* the *quoin*, and *c p* the *piers*. Sometimes the wall is cased on both sides with cut stone, the middle being filled with rubble, as in fig. 201, in which case *heading* or *bond* stones *bb* are carried at intervals through the thickness of the walls to prevent the sides from being forced apart by the interposed rubble.

When the top of a stone wall is horizontal the bedding-joints should be so too, but in bridge building and walls on inclined surfaces the bedding joints may follow the directions of the work. The footing of the stone walls should be made with stones as large as can be procured, squared and of equal thickness in the same course with the broadest bed downwards. The vertical joints in the upper courses must *break joint, i.e.* must not fall on those below. The header and stretcher system, as adopted by the bricklayer, may also be employed. Foundations should usually consist of several courses, decreasing in breadth as they rise, by *sets off* on each side of 3 or 4 inches, the number of courses being regulated by the weight of the wall, and by the size of the stones in these footings or foundations.

The walls built by the ancient Romans are still celebrated for their strength and solidity. The stones were usually laid in mortar, but where large blocks were used no cement was employed. Fig. 204 is a specimen of what is called *Roman emplectum*, in which the middle of the wall is of rubble. In some cases courses of tiles were built in at intervals, their large surfaces making a good bond. After the Romans had quitted Britain, various new forms of masonry were adopted, mostly inferior to the Roman. The quoins, the jambs of doors and windows, and some other parts were built of hewn stone in blocks alternately laid flat and set up on end, forming what is called *long and short* work (fig. 203). In the twelfth century the character of masonry improved; the mortar was finer, the stones were set with close fine joints, and ashlar was more generally used for the facing. Fig. 205 is a specimen of Italian masonry.

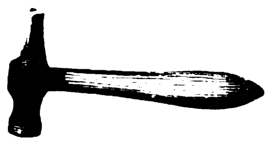
X.—THE CARPENTER AND JOINER.

It is the business of the carpenter to frame and put together roofs, partitions, floors, and other necessary parts of the building. The joiner begins his work where the carpenter leaves off, for it is his business to supply and fit up stairs, cupboards, furniture, and other parts required for convenience. We may illustrate some of the most important terms used in carpentry by means of two kinds of roof represented in figs. 234, 235. Pieces of timber laid on the wall in order to distribute the pressure of the roof equally, and to bind the walls together, are called *wall-plates*, or *raising-plates*, as at *a a*, while the horizontal piece of timber *b b*, connected to two opposite principal rafters, is called a *tie-beam*. It serves the purpose of preventing the walls from being pushed out by the thrust of the roof, and also of supporting the ceiling of the room below. When placed above the bottom of the rafters it is called a *collar-beam*. The two pieces of timber in the sides of the truss which support a grated frame of timber over them for receiving the roof-covering or slating are called the *principal rafters*, as at *c c*. The horizontal pieces of timber *d d*, notched on the principal rafters on which, and on the pole-plates, the common rafters rest, are called *purlines*, while the pieces of timber *e e* placed at equal distances on the purlines, and parallel to the principal rafters, are called *common rafters;* their use is to support the boarding to which the slating is fixed. The pieces of timber *f f*, which rest on the ends of the tie-beams and support the lower ends of the common rafters, are called *pole-plates*. At *g* (fig. 234), is an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam; this is called a *king-post*, and its use is to prevent the tie-beam from sinking in the middle. *Queen-posts*, *i i*, fig. 235, are two upright pieces of timber framed below into the tie-beam, and above into the principal rafters; they are placed at equal distances from the middle of the truss or its ends. *Struts* or *braces*, *h h*, are oblique straining-pieces framed below into the queen-posts or king-posts, and above in the principal rafters, and supported by them. *Puncheons* or *studs* are short transverse pieces of timber fixed between two others for supporting them equally. A *straining beam*, *k*, fig. 235, is a piece of timber placed between the queen-posts at their upper end so as to withstand the thrust of the principal rafters; while a similar piece placed upon the tie-beam at the bottom of the two queen-posts for resisting the force of the braces which are acted on by the weight of the covering, is called a *straining-cill*, middle *i*, fig. 235. There are other terms, such as *camber-beams*, or horizontal pieces of timber made sloping on the upper edge from the middle towards each end, for discharging the water. *Auxiliary rafters, principal braces*, or *cushion rafters*, are pieces of timber framed in the same vertical plane with the principal rafters under, and parallel to them, for giving additional support.

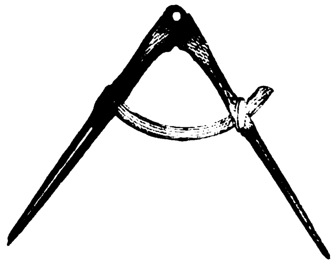
An important part of the business of the carpenter is that of *joints*. These may be used for lengthening timbers, or they may be *framing* and *bearing* joints, used in trusses, flooring, &c. or joints for ties and braces. Timbers may be connected lengthwise by bringing the two beams end to end, placing a short piece on each side, and bolting through these short pieces and the main beams; but this is not a neat method; it is therefore more common to apply the operation of *scarfing*, in which case one-half of the substance of each beam is cut away for a short length, and the cut portions being brought together are fastened by means of screws, straps, bolts, or wedges. Thus the common *scarf-joint* (fig. 224) is made by halving each piece of timber for a certain length, and bolting or strapping the two pieces together; but where it is an object to secure strength in resisting longitudinal strains, such a joint as that shown at fig. 230 is employed either with or without bolts. The French scarf-joint (fig. 231) is called, from its fancied resemblance to the form of a flash of lightning, *traits de Jupiter;* this figure also shows the method of applying bolts and straps. Fig. 237 shows a *longitudinal joint* which may be used where a vertical pressure only is to be borne. Fig. 233 shows a *framing-joint* used in the construction of a principal rafter. Such joints are made on the principle of a *tenon* and *mortise*, in which one of the pieces to be joined is cut away

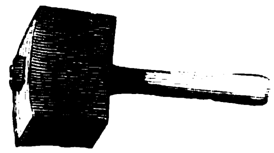

206. BRAD.


207. CUT CLASP NAIL.

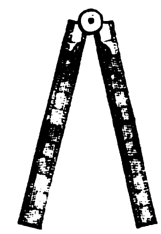

208. HAMMER.


209. NARROW SAW.


210. COMPASSES.


211. MALLET.

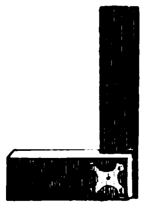

212. CLOUT NAIL.

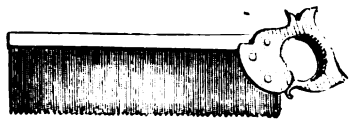

213. 2-FOOT RULE.


214. BRAD-AWL.


215. CHISEL.

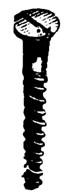

216. GIMLET.


217. SQUARE.

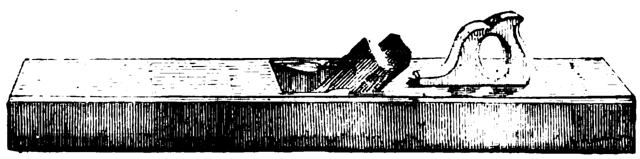

218. TENON SAW.

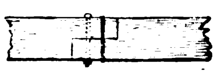

219. AXE.

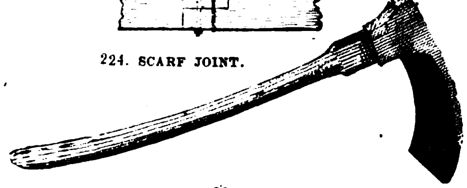

220. SCREW-DRIVER.

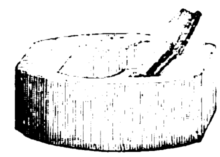

221. SCREW

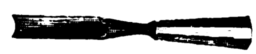

222. SPIKE NAIL.

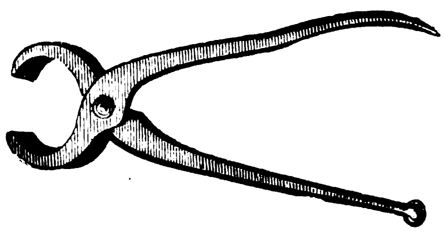

223. TRYING PLANE.


224. SCARF JOINT.

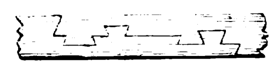

225. ADZE.

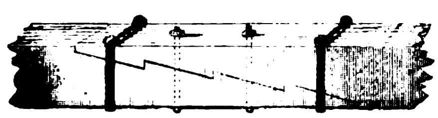

226. SMOOTHING PLANE.


227. GOUGE.

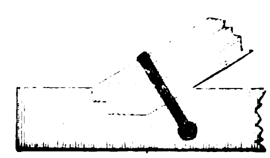

228. PINCERS

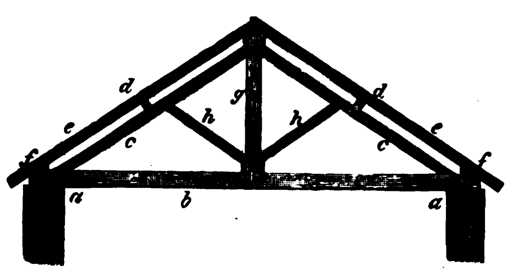

229. CHISEL.


230. SCARF JOINT.

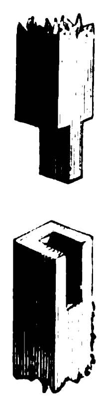

231. FRENCH SCARF JOINT.


232. THE CARPENTER'S SHOP.

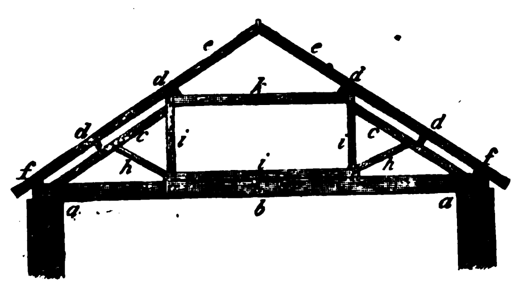

233. RAFTER.



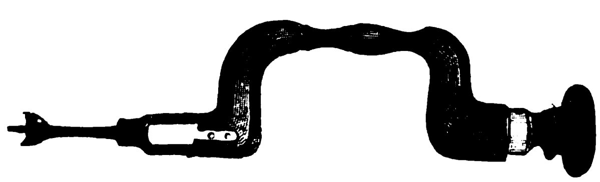
234. KING TRUSS.

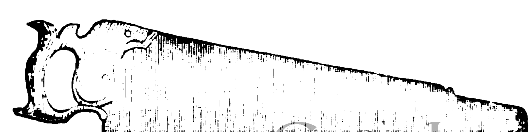

237. LONGITUDINAL JOINT.


238. GLUE POT.



235. QUEEN TRUSS.


236. BRACE AND BIT.


239. HAND SAW.

so as to leave a small projection or tenon, while a corresponding cavity or mortise is made in the other piece to receive the tenon.

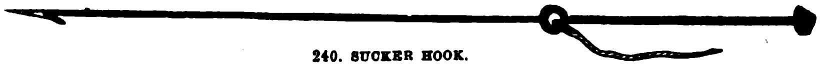
There are many other particulars which might be given respecting floors and partitions, &c.; but enough has been said to show the nature of the house-carpenter's work. The various tools used by him are represented in the figures, not very accurately indeed, but they are all so well known that the defects of the figures may be supplied by the experience of the reader. In carpenters' work the timber remains rough, as left by the saw; but in joiners', it is brought to a smooth surface by means of the plane, wherever it is exposed to view. The chief cutting tools used by the joiner consist of saws, planes, and chisels. There are various kinds of saws, distinguished by their shape and the size of the teeth: thus the *ripper* has 8 teeth in a length of 3 inches; the *half-ripper* 3 teeth to the inch, the *hand* saw (fig. 239) 15 teeth in 4 inches, and the *panel* saw 6 teeth to the inch. The *tenon* saw (fig. 218), which is used for cutting tenons, has about 8 teeth to the inch, and the blade is prevented from *buckling* or bending by means of a thick piece of iron at the back. The *sash* saw has a brass back, and 13 teeth to the inch, while the *dove-tail* saw has 15. The *key-hole* saw (fig. 209) is used for cutting out small holes. There are also various kinds of planes: those used for bringing the stuff to a plane surface are called *bench* planes, and of these the *jack* plane is used on the roughest work, while the *trying* plane (fig. 223) is used after the jack plane for *trying-up*, or taking off shavings of the whole length of the stuff. There is also the *long* plane, 2 feet 3 inches in length, the *jointer*, 2 feet 6 inches in length, and the *smoothing* plane, 7½ inches in length, used for cleaning off finished work. There are also various *moulding* planes for forming or *sticking* mouldings, as it is called. Chisels (figs. 215, 229) are also of various forms and uses, such as the *paring chisel*, which is used by the pressure of the hand only; the *socket chisel*, used with the *mallet* (fig. 211). The *gouge* (fig. 227) is only a curved chisel. The boring tools are the *brad-awl* (fig. 214), the *gimlet* (fig. 216), the *brace and bit* (fig. 236), the latter admitting into the handle or *stock* a variety of *steel bits* of different bores and shapes for boring and widening holes in wood and metal. The joiner also uses the *screw-driver* (fig. 220), the *pincers* (fig. 228), the *hammer* (fig. 208), the *axe* (fig. 219), and the *adze* (fig. 225). It may be remarked that the *glue-pot* (fig. 238) is not used by the house-carpenter or joiner, but belongs rather to the cabinet-maker.

XI.—THE SLATER AND THE PLUMBER.

UNDER this head we may briefly refer to the various materials used for roof coverings, of which there are three classes; namely, stone, wood, and metal. Slates belong to the first kind: those from Wales, which are of a light blue colour, are considered the best. Slates from Westmoreland are of a dull greenish hue. They are of various sizes, and the Welsh slates are distinguished by odd names, such as *doubles*, 1 foot 1 inch by 6 inches; *ladies*, 1 foot 4 inches by 8 inches; *countesses*, 1 foot 8 inches by 10 inches; *duchesses*, 2 feet by 1 foot; *imperials*, 2 feet 6 inches by 2 feet; *rags*, and *queens*, 3 feet by 2 feet. The slater uses tools common to other trades, but there is one tool especially his own, called a *saixe*, *sax*, or *zax*. It is a kind of hatchet or chopper, with a sharp point at the back: with this he trims the slates and makes the holes by which they are fastened in their places. Slates are laid either on boarding, or on narrow battens, from 2 to 3 inches wide; the latter being the less expensive method. The slates are fastened by means of copper or zinc nails, and each slate should be secured with two nails. The upper surface of a slate is called its *back*, the under one the *bed*, the upper edge the *head*, and the lower edge the *tail*. The portion of each course which is exposed to view is called the *margin*, and the width of the margin, the *gauge*. The distance which the lower edge of one course overlaps the slates of the next lower course, measuring from the nail-hole, is called the *bond* or *lap*. The method of attaching the battens to the rafters and fastening the slates will be understood by referring to fig. 260. Sawn slate is also used for chimney-pieces, shelves, cisterns, baths, and ornamental purposes.

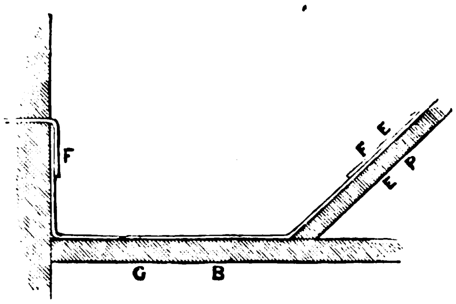
In places where laminated stone, or stone that can be easily split, is abundant, thin slabs are used for roofing, but this kind of covering is very heavy, and requires strong timbers for its support. Tiles form another covering: when flat, they are called *plain* tiles, and when curved so as to lap over each other at the sides, *pan* tiles. Wooden coverings, such as *shingles* of split oak, are sometimes, but not often, used for coverings. Metallic coverings consist of thin sheet *copper* (but this is too expensive for general use); sheet *zinc*, which is both light and cheap; *iron*, coated with zinc, to protect it from rust, which has, of late years, come into general use; but the most common material is *lead*, which has the advantages of being easily spread out and adjusted to different surfaces, of being very durable, and of resisting the action of the weather. It is cast in sheets, of the weight of from 4 to 8 lbs. to the square foot, either by spreading it out in a molten state on a large table covered with sand, as in fig. 254, or by passing it through a rolling mill. In the latter case, it is called *milled lead*. In casting sheet lead, the metal is made fluid in a cast-iron *melting pot*, from which it is ladled into a trough, called the *pan*, the length of which is equal to the width of the casting table. The trough is then tilted up and the melted lead poured out, when a wooden strike is passed over the surface of the metal, so as to spread it evenly over the table, or the trough itself may have a narrow aperture along its bottom, and when filled with melted lead be moved along the table, the lead flowing out as it advances. The thickness of the sheet will depend on the size of the aperture and the quickness with which the trough is moved over the table.

Metallic coverings are liable to great contraction and expansion by exposure to the weather. We have seen a copper roof covering puckered up in a most extraordinary manner by the heat of the sun. To prevent this, the joints should not be soldered or nailed, but should be *flashed*, that is, the edges should be turned down over the edge of another sheet, which is turned up against the wall, as at *F*, fig. 243, for which purpose the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flashings inserted into the crack at the upper side, while the lower edge is dressed over that of the lead in the flat or gutter. In fig. 243, *G B* is the gutter board, *E P* the eaves board, and *F E* the foot of the eaves course. As the sheets do not exceed 6 feet in breadth, water-tight joints are made by forming *laps* or *rolls*. A roll is a strip of wood, *R*, fig.

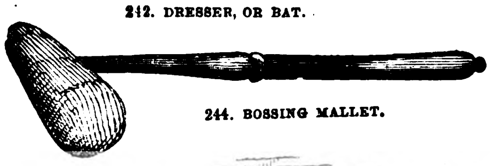

240. SUCKER HOOK.

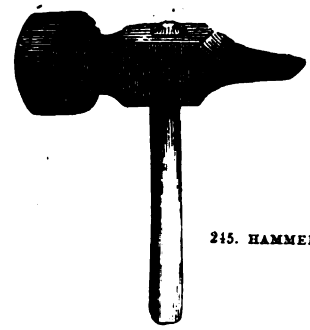

241. SCREWDRIVER.

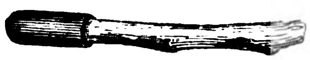

242. DRESSER, OR BAT.



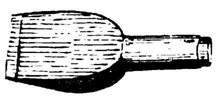
243. LEAD COVERING FOR GUTTER.

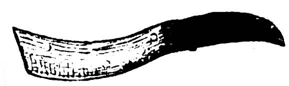

244. BOSSING MALLET.

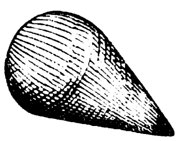

245. HAMMER.

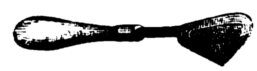

246. DUNRING.


247. CHIPPING KNIFE.


248. CHASED EDGE

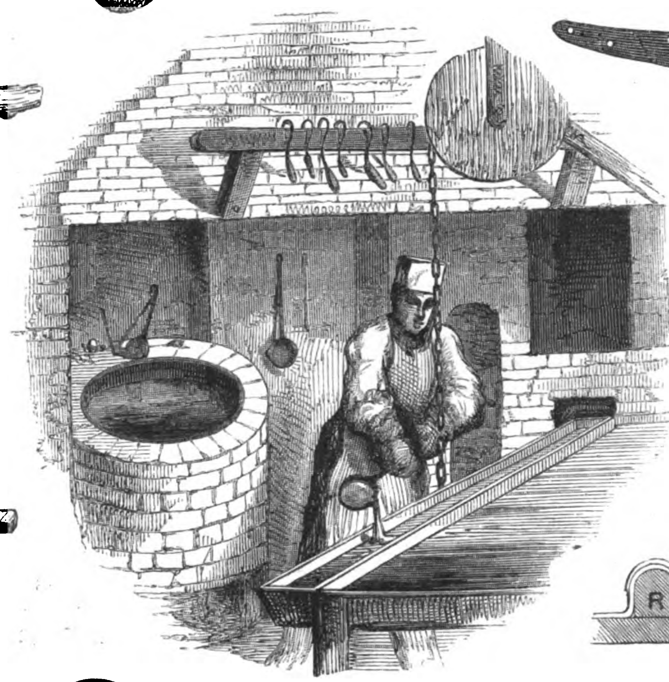

249. DRAWING KNIFE.

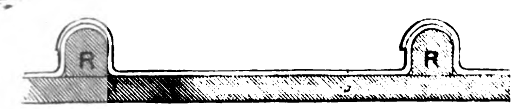

250. TURNPIN.


251. SHAVE HOOK.


252. SHAVE HOOK.


253. POURING STICK.

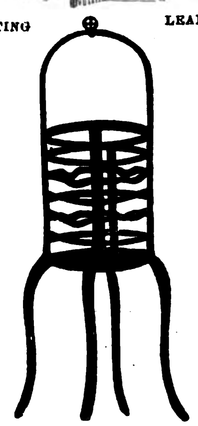

254. CASTING LEAD.



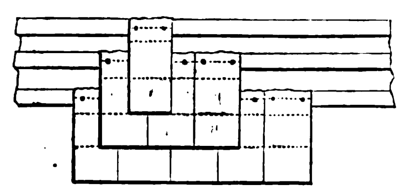
255. LAP OR ROLL.


256. SOLDERING IRON.


257. LADLE.


258. GRATE.


259. CHISEL.


260. SLATERS' WORK.

255, about 2 inches square, rounded on its upper side, over which one of the edges of the lead is dressed, and is covered by the edge of the adjoining sheet, and the whole being well hammered down, a water-tight joint is formed without any fastening. Lead flats and gutters should be made with a fall or *current,* as it is called, to keep them dry. The fall is usually from back to front, or in the direction of the length of the sheet. A quarter of an inch to the foot is a sufficient inclination, and the carpenter provides this while preparing the ground or platform for the lead.

Cisterns are usually made of wood or masonry on the outside, and are lined with sheet lead, the joints being secured by solder. Water trunks and pipes are fitted with large case-heads above, for receiving the water from gutter spouts, and with shoes below for delivering the water. They are attached to the walls by means of flanches of lead, and secured by spike nails. Service and waste pipes are attached by means of iron holdfasts.

The plumber requires but few tools. He is furnished with a *hammer* (fig. 245), wooden *mallets* of different sizes, and a *dressing* and *flatting* tool (fig. 242). This is of beech, about 18 inches long, and 2½ inches square, flat on the under surface, and rounded on the upper, with a handle at one end. This is for stretching out and flattening the lead, and dressing it to the required shape. The plumber also uses a *jack* and a *trying* plane for reducing the edges of sheet lead to a straight line. His cutting tools are *chisels, gouges,* and *knives* (figs. 247, 249) for cutting the sheet lead into slips and pieces, after marking it out with a chalk line. He also uses *files,* and when joints are required, the *soldering iron* (fig. 256), the joints being prepared by means of *shave-hooks* (figs. 251, 252). Solder is melted in a *ladle* (fig. 257), over a fire contained in the grate (fig. 258). The solder, called *soft solder,* is made of equal parts of lead and tin. The joints are smoothed down by means of *grozing* irons.

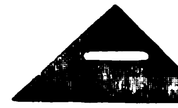
XII.—THE PLASTERER AND WHITEWASHER.

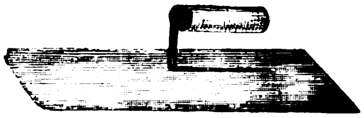
The business of the plasterer is to apply plaster or cements to walls, ceilings, &c. in order to conceal the roughness of the brick-work or masonry, or the timber framing of partitions, floors, roofs, and staircases, and also to allow the painter, paper-hanger, and house-decorator to begin their work. The plasterer has also to make and fix ornamental cornices, centre-pieces, &c. When a wall is to be plastered, the bricklayer leaves the joints rough and prominent so that the plaster may adhere; and in plastering old walls, some of the mortar is removed from the joints, and the surface of the brick-work made rough by *stabbing* and *picking* it over. In plastering upon partitions, or on the under surface of timber floors, *laths* are nailed to the timber quarterings or to the joists. Laths are usually of fir-wood about one inch in width, and from 3 to 5 feet in length; the thickness varies from a quarter-inch or *single lath,* to three-eighths or *lath and a half;* and half an inch or *double:* they are nailed across the joints with cast-iron nails. The first coat of plaster, called *course stuff,* is made of lime and sand mixed with ox or horse-hair, and is applied with a *trowel* (fig. 261), in such a way as to force the mortar into the narrow openings between the laths; behind which it hardens in small lumps, and thus becomes *keyed* firmly to the laths. When only two coats are applied, plastering is called *laid and set:* the first coat or the *laying* is levelled with the trowel, and when dry the surface is scratched up with a birch broom, and a thin coat or *set* of finer plaster is laid on and smoothed with a trowel. In applying one coat upon another, the surface is sprinkled with water by means of a bristle brush. In the better kind of work the first rough coat is scored over with a pointed lath, with cross lines 3 or 4 inches apart, to allow the second coat to adhere. The first coat may project a quarter or three-eighths of an inch from the laths, when it is called *pricking up.* When sufficiently dry, ledges of plaster six or eight inches wide, called *screeds,* are placed at the angles, and at intervals of a few feet across the surface to nearly the degree of projection or level of the finished surface, so as to serve as gauges for the rest of the work. The spaces or bays between the screeds are filled up flush with them, and the plaster levelled by means of flat wooden *floats* (fig. 275), made with one or two handles, those with two handles being called *Derbys* or *Derby floats: straight edges* (fig. 277), or long pieces of wood planed to a straight edge, are also used. When the second coat is dry it is swept over, and a third coat of *fine stuff* or plaster of fine white lime is carefully applied so as to form a smooth hard surface. When plaster is applied to a brick or stone wall, the first rough coat is called *rendering.* Fine surfaces such as ceilings, which are to be whitewashed or coloured, are finished with a fine plaster of the best powdered lime, well worked with water into a paste or *putty* as it is called. When surfaces are to be papered, a somewhat coarser stuff mixed with a little hair is used. Surfaces intended to be painted on are finished or set with bastard stucco formed of two-thirds ordinary fine stuff without hair and one-third fine clean sand; the last coat being finished with the trowel without the float.

The plasterer has a labourer to supply his boards with mortar, and a boy to feed his *hawk* (fig. 269), which he does with the *salve* (fig. 278). The hawk is a piece of wood 10 inches square, held by a projecting handle at the bottom. The *laying-on trowel* (figs. 261, 263) is a thin plate of hardened iron or steel rounded at one end and square at the other, with a handle at the back. The *gauging trowel* (fig. 279) is used for gauging fine stuff for cornices, &c. The *drag* (fig. 280) is a two or three-pronged rake, used for mixing the hair with the mortar in preparing coarse stuff.

Cornices may be plain or ornamented. If they project more than 7 or 8 inches, *brackets* or pieces of wood are fixed 11 or 12 inches apart, and laths are nailed to them to support the plaster. A mould or profile of the intended cornice is made of beech-wood, with the *quirks* or small sinkings of brass. When a sufficient quantity of plaster has been laid on, the mould is held steadily and firmly to the ceiling and wall, and moved backwards and forwards, the effect of which is to shape the plaster to the form of the mould. Large cornices may require 3 or 4 moulds, and some parts may have to be modelled and filled up by hand with the assistance of the tools figs. 264, 267. Ornaments may be attached by means of plaster of Paris. The ornaments are cast in plaster of Paris from clay moulds, but of late years other materials have been introduced, such as *carver's compo,* consisting of a mixture of whiting, resin, and glue; *papier maché,* with a priming of whiting and glue over it for sharp impressions; *carton pierre,* with layers of whiting and glue; and *gutta percha.*


261. SETTING TROWEL.


262. SET SQUARE.

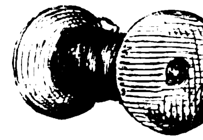

263. SETTING TROWEL.

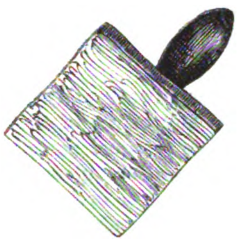

264. MODELLING TOOL.

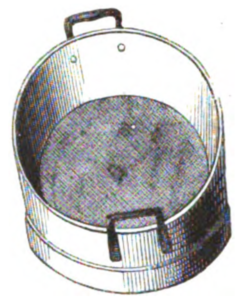

265. BRUSH.


266. HAMMER.


267. MODELLING TOOL.

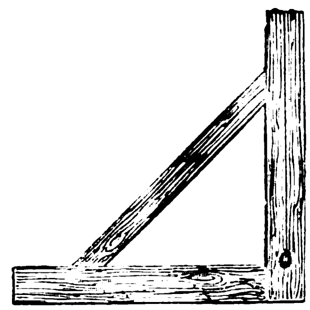

268. CHECK LINE AND REEL.


269. PLASTERER'S HAWK.


270. FINE SIEVE.


271. COMPASSES.


272. PLASTERER AND WHITEWASHER.

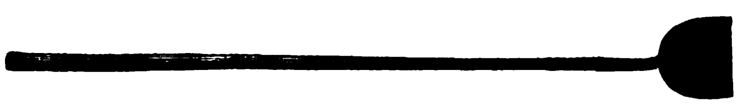

273. SQUARE.


274. JOINT RULE.


275. HAND FLOAT.


276. JOINT RULE.


277. FLOATING RULE.


278. SALVE.


279. GAUGING TROWEL.


280. HAIR HOOK.

The plasterer makes use of a variety of compositions and cements. For the external coatings of buildings *Roman cement, Portland cement*, and *lias cement* are used; while for delicate internal work, *Martin's* and *Keene's cement* are employed.

When the plasterer has completed his work, the whitewasher gives the whole a finished appearance by means of a lime wash, applied by means of a brush (fig. 265). In fig. 272, the plasterer and whitewasher are represented at work at the same time: this is a mistake, as it is necessary that the plasterer's work should be dry or nearly so before the whitewasher begins.

XIII.—THE HOUSE-PAINTER AND GLAZIER.

THE work of the house-painter is to cover with a preparation of white lead and oil such parts of the joiner's, smith's, and plasterer's work as require to be protected from the action of the air. *Decorative painting* is a higher branch, and requires artistic skill. White lead is the basis of all ordinary paints, and forms at least nine-tenths of their composition. The paints may be ground on a stone or *slab*, with a *muller* (fig. 284), but the work is usually done on a large scale by the manufacturing chemist in paint mills, which resemble in some respects the mill used for grinding corn. White lead and linseed oil are chiefly employed, but other substances are used, such as colouring matters, or *stainers*, as they are called; also, drying materials, or *dryers*. The linseed oil is sometimes boiled, which assists the drying, but makes it thick, so that it is only fit for outdoor work. Spirits of turpentine, or *turps*, is much used. Litharge and sugar of lead, ground in oil, are employed as dryers, together with japanners' gold size. Among the pigments used as stainers are ochre, Venetian red, lamp-black, Indian red, Turkey and English umber, terra de Sienna, red lead, Prussian blue, orange red, chrome yellow, vermilion, &c.

The painter prepares surfaces for painting by rubbing them over with a flat face of pumice stone or with sand-paper, or by filling up the holes with putty. He punches in the heads of nails and stops them with putty. Knots in the wood, which would bulge out or leave a stain, are cut out, and pieces of wood glued in instead. In common work, the knots are painted over with red lead and size.

In painting plaster walls, four or five coats are required. The first consists of white lead made thin with linseed oil, and a little litharge is added to insure the drying. The plaster absorbs the oil and becomes hard on the surface. A thin second coat is added to saturate the plaster. The third coat is thicker, and contains some turps and a little of the colouring matter, while the fourth coat is quite thick. The colour is used several shades darker than the finishing coat, and the dryer is sugar of lead. Each coat is rubbed lightly over with sand-paper before the next one is applied. The finishing or *flatting coat* (as it is called, because it dries without gloss) is of pure white lead, diluted with spirits of turpentine only: it darkens in drying, and hence is used lighter than the pattern. A little japanners' gold size is used as the dryer.

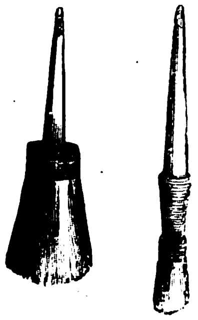
In painting wood, a similar course is to be adopted, each coat being thicker and smoother than the previous one. In imitations of oak, marble, &c. there is first a groundwork of four or five coats, and care is taken not to leave any marks of the brush. The last coat is not flatted, but consists of equal parts oil and turps; the shades and grain of the wood are given by thin glazings of Vandyke brown, terra de Sienna, or umber, &c.; these are ground in water, and mixed with small beer, which is slightly glutinous, and the whole is finished with a coat of varnish. Wainscot is painted thick, so that it may receive the impressions of an ivory or horn *comb* (fig. 299) by which the grain of the wood is imitated. A copal varnish is then applied. Imitations of marble, &c. belong rather to decorative painting.

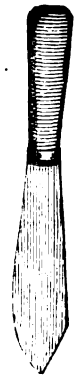
The painter works with *brushes* of hogs' bristles of different sizes (figs. 281, 282). The colours are contained in earthen *pots* (fig. 285), or in *kettles* (figs. 287, 298); the painter is also furnished with *cans* (fig. 293), for holding oil, a *palette knife* (fig. 286), for taking colour off the slab, and a *stopping knife* (fig. 283).

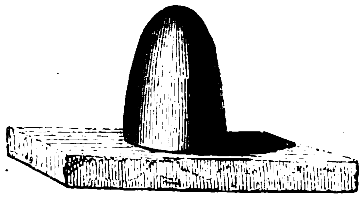
The work of the glazier is to cut out glass and fix it into lead-work or sashes. The sash-bars have a *rebate* outside for receiving the glass, which is *bedded* and *back-puttied* to secure it in its place. Putty is made of whiting and linseed oil, beaten together. Large squares of glass are also secured or *sprigged* with small brads driven into the sash-bars.

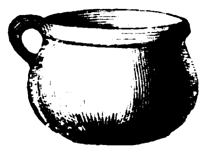
Lead-work is prepared by passing leaden rods, called *cames*, through a *glazier's vice*, which forms the grooves in which the glass is inserted. The bars are soldered together, so as to form squares or diamonds. The sides of the grooves are then turned down to receive the small panes, after which they are pressed firmly up against them.

The glazier cuts his glass by means of an unpolished *diamond*, fixed in lead, and attached to a handle of hard wood (fig. 296). With this he traces a line across the glass, when a slight pressure on each side of the cut determines the fracture in the right direction. If the diamond be properly used, a true cut is produced, while a diamond with angles formed artificially gives only a scratch with ragged edges. The cut need not penetrate to a greater depth than the two-hundredth part of an inch. The glazier also uses a *hacking-out knife* (fig. 291), for getting out old putty; a *stopping knife* (fig. 288), for laying in and smoothing the putty; a *setting knife*, for setting glass in lead work; a *square* (fig. 297), a *straight edge* (fig. 300), a *two-foot rule* (fig. 295), a pair of *compasses*, for dividing the large sheets or *tables* of glass to the proper sizes, a *hammer* (fig. 294), for the sprigs, and a *brush* (fig. 301), for cleaning off his work.

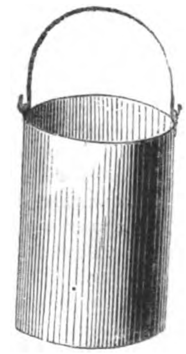

281, 282. PAINT BRUSHES.

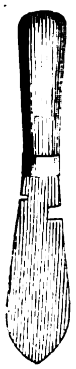

283. STOPPING KNIFE.


284. MULLER AND SLAB.

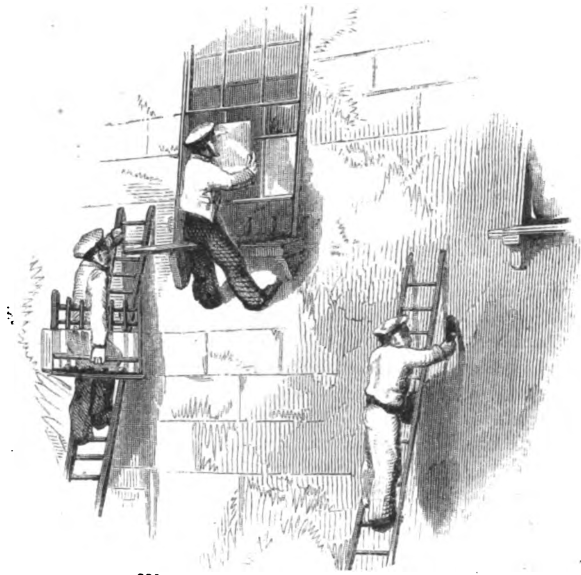

285. PAINT POT.

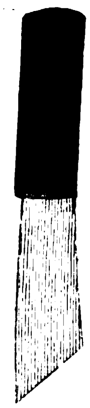

286. PALETTE KNIFE.

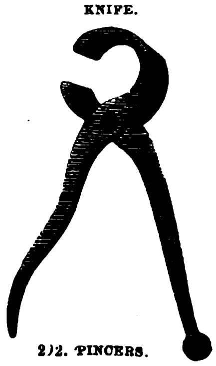

287. PAINT KETTLE.


288. GLAZING KNIFE.

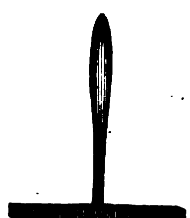

289. CHISEL KNIFE.

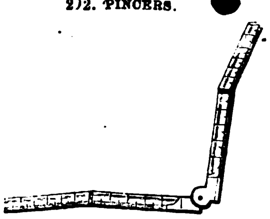

290. HOUSE-PAINTING AND GLAZING.


291. HACKING KNIFE.

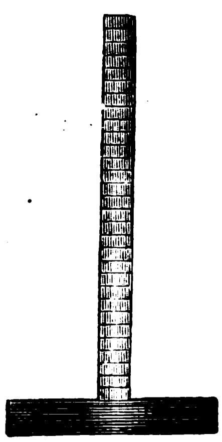

292. PINCERS.

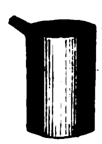

293. OIL CAN.


294. TILTER.


295. TWO-FOOT RULE.


296. DIAMOND.


297. SQUARE.


298. PAINT POT.


299. GRAINING COMB


300. RULE.


301. GLAZIER'S BRUSH.

XIV.—THE PAPER-STAINER AND PAPER-HANGER.

The practice of covering the walls of apartments with ornamental paper-hangings adds greatly to their comfort, and is not without its effect in promoting cheerfulness in the occupants. A room with a cold northern aspect is relieved by being papered with a rose or crimson colour, or with paper in which the warmer tints prevail; while a room with a bright southern aspect may be equally relieved by an admixture of a cold colour, such as a bluish green. The apparent size and height of a room are also influenced by paper-hangings: those with a large pattern reduce the apparent size: those with a large and flowing pattern reduce the height; but where vertical lines occur, even though the pattern be large, the height is not so much affected. A small room should not be covered with a large pattern, but both pattern and colours should be quiet and harmonious, and like the background of a picture should rather relieve and set off the objects in front and give repose to the eye. Sudden contrasts of colour should also be avoided, and it is generally in bad taste to attempt architectural effects, such as columns, friezes, pilasters, &c. Some of the most pleasing effects may be produced by means of flowers and conventional forms, and it has even been proposed to introduce short choice sentences from some of our best writers; but this would require the exercise of a sound judgment and good taste.

There are various methods of producing paper-hangings. An early method is that of *stencilling*, in which a piece of pasteboard or sheet metal with a pattern cut out in it was placed on the paper, or even on the whitewashed wall of the room, without the intervention of paper, and water colours being brushed over the back of the stencil would pass through the openings and produce the patterns on the paper or wall. When the first colour had become dry, a second stencil could be applied with a second colour, and in like manner a third and a fourth, and thus by the repeated applications of the stencil-plates the wall would be furnished with a pattern in a number of colours.

Another method of producing paper-hangings is by hand-printing, a process which closely resembles calico-printing by hand, and floor-cloth printing, as described in our *Illustrations of Manufactures.* The pattern is contained on blocks of pear-tree or sycamore, mounted on poplar or pine-wood (figs. 308, 310). Each block has four pin-points at the corners to serve as guide-marks in placing the blocks with other colours. Each colour is distributed over a sieve or drum of calf-skin (fig. 316), floating in a tub of water, thickened with parings of paper from the bookbinder's.

An attendant keeps the drum well covered with colour, and the printer, pressing the block upon the skin, transfers it to the paper and presses it down with the assistance of a lever worked by the foot (fig. 309). When the piece has been printed in one colour, it is hung up to dry. *Flock paper* has the pattern first printed in size and varnish, and before this is dry, coloured flock, prepared from wool, is dusted over it. The flock is obtained from the shearing machines of the woollen cloth manufacturer. Unless already coloured, it is scoured and dyed to the proper tint, then stove-dried, ground to powder, and sifted. It is next placed in a large chest or drum (fig. 304), and the flock sprinkled over it. When about 7 feet of paper have been drawn in, the lid of the drum is closed, and the calf-skin bottom beaten with rods. This causes the flock to rise in a cloud, which as it subsides falls uniformly on the paper. Gradations of colour in the flock are afterwards produced by applying shades in water-colour or in distemper.

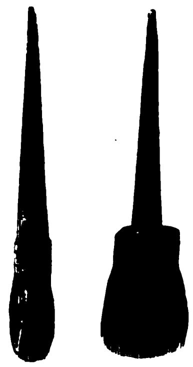
Paper-hangings are also produced by cylinder printing, in which as many as from 14 to 20 colours are produced, and one machine is capable of producing from 1,000 to 1,500 pieces a day.

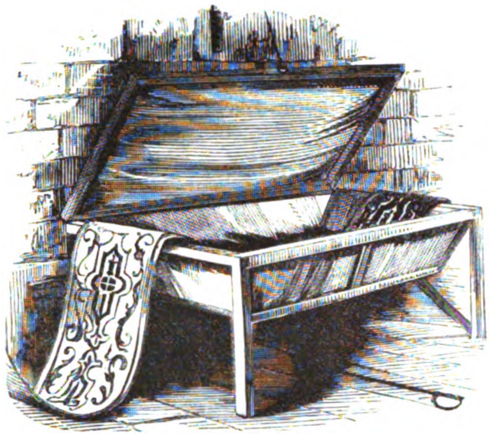
A piece of paper is 12 yards long and 20 inches wide, and when hung covers 6 feet superficial.

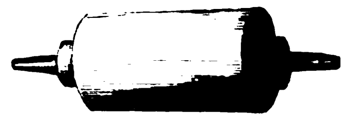
XV.—THE TAILOR.

Having noticed some of the more important trades connected with the preparation of food and shelter, we proceed to give a few details respecting one or two trades concerned in the preparation of our clothing. In our *Illustrations of Manufactures*, we showed the various modes by which woven fabrics are prepared, not only as it respects the different textile fabrics of cotton, linen, silk, and wool, but also the peculiar kind of weaving by which hosiery is prepared, and the art of felting, by which beaver hats are produced. The method of making silk hats was also explained. The processes by which various kinds of leather are prepared were also illustrated. It will be seen from those details how large and important a part of our national industry is concerned in the preparation of clothing. The trades which are concerned in the cutting out and otherwise preparing the materials furnished by the manufacturer are numerous, and employ a large number of persons of both sexes. Thus, in the preparation of female attire the milliner prepares the lighter portions, such as bonnets, caps, collars, cuffs, fancy pelerines, capes, &c.—the dressmaker is chiefly employed in the preparation of ladies' robes, and the mantle-maker prepares the mantles and outer clothing. All females, however, are or ought to be acquainted with the use of the needle, from the child who makes clothing for its doll, to the matron who fabricates with her own hands a great portion of the wearing apparel of the females of her household. With respect to articles of men's attire, the case is different: they are prepared by persons who have been regularly trained and instructed in the tailor's art, and there is scarcely any attempt made at the domestic manufacture of their outer clothing.

It is difficult to explain in writing processes which depend so eminently on skill of hand, and that peculiar dexterity or *right-handedness*, as the word means, which can only be acquired by constant practice. The first step in preparing a suit of clothes is to ascertain the proper dimensions by applying a flexible *measure* (fig. 317) to the various parts of the body of the person for whom they are intended. In measuring for a waistcoat, all that is necessary is to ascertain the length, and the size round the breast and round the waist. The measures for coats and trousers are more difficult. For a coat the following dimensions must be taken:—1, the length of the waist; 2, the length of the coat;

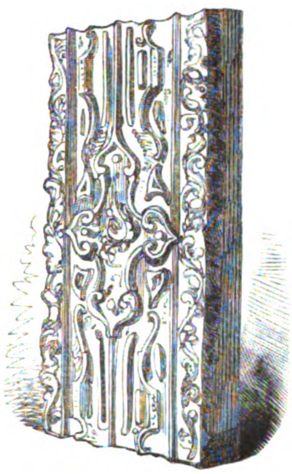

302, 303. PAINT BRUSHES.

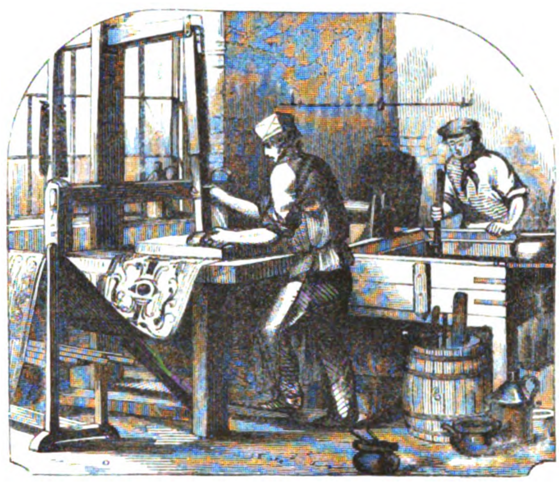

304. DRUM FOR LAYING ON FLOCK.

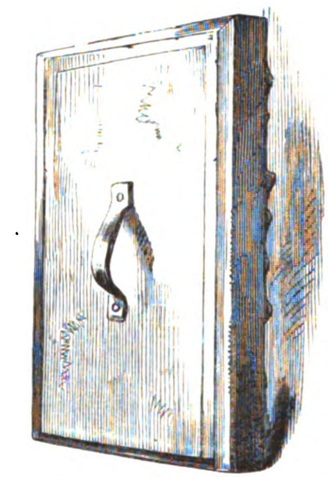

305. COLOUR DRUM.


306. PAINT POT.


307. SIZE CAN.


308. FRONT OF PRINTING BLOCK.

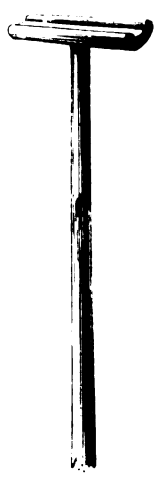

309. PRINTING PRESS.

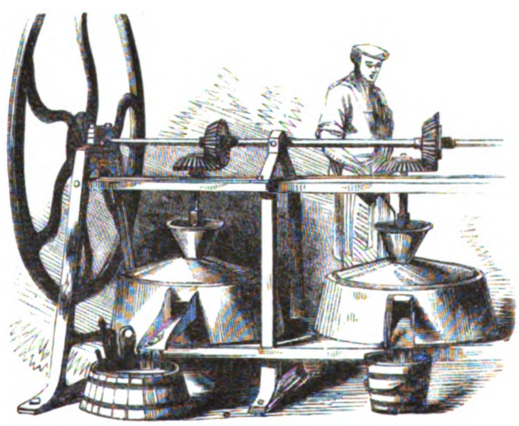

310. BACK OF WOODEN BLOCK FOR PRINTING.

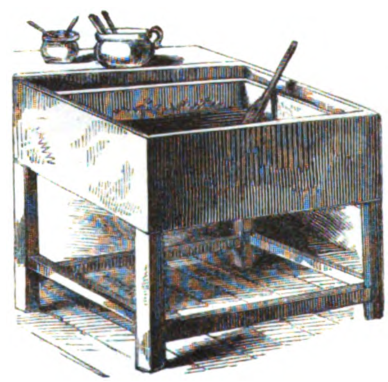

311. HAND BRUSH.


312. SPAT.


313. LADLE.


314. CRUTCH.

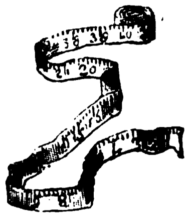

315. COLOUR-GRINDING MACHINE.


316. COLOUR SIEVE.

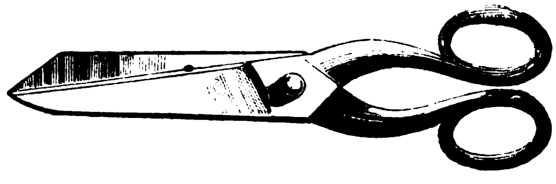
3, the distance from the middle of the back to the elbow, and from thence to the bottom of the sleeve; 4, the size of the arm at the top, just above the elbow, and also at the wrist; 5, the length of the front, measuring from the top of the back seam to the bottom of the lappel; 6, the size of the breast just under the arms; 7, the size of the waist; 8, the height of the collar. These dimensions being taken, and entered in the *measure-book* (fig. 330), and the customer having selected the proper pattern from the samples submitted to him in the *pattern-books* (figs. 324, 331), the next step is to cut out the cloth, for which purpose it is spread out quite smooth upon a cutting board; the various parts are marked out with *chalk* (fig. 328), with the assistance of the *rule* (fig. 332). The next step is cutting out by means of the *shears* (fig. 319). This is a difficult art, and forms a distinct branch of the trade, many men earning their living solely by practising it. The work of the tailor, properly so called, is very simple. His tools are few and inexpensive. He requires a yard of linen for a *lap-cloth;* two pairs of *scissors*, one pair moderately large for common use, and the other small, for cutting out button-holes; a *thimble* (fig. 329), a piece of *bees-wax* (fig. 333), for waxing his thread; needles and thread (figs. 334, 335), a *sleeve-board* (fig. 318), an *iron* and a *holder* (figs. 322, 321), and a *goose* and *stand* (figs. 323, 326). The goose is so called from its handle, which resembles the neck of the well-known bird.

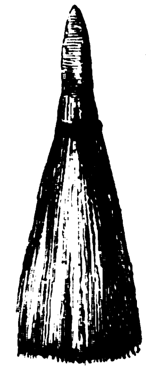
There are various kinds of stitches used by the tailor, such as the *basting-stitch*, which is long and slight, usually intended to keep the work in its proper position while being sewed; the *back-* and *fore-stitch*, in which the needle is first put through the cloth, and turned up in as short a space as possible, so as to make a neat, strong stitch; it is then put through the cloth again in the same place, and again turned up, so as to pass through the cloth as before: the seam is finished by a series of such stitches. The back-stitch is sometimes used without the fore-stitch. Then there is the *side-stitch*, used for the edges of garments, in which the needle is passed through the cloth a little above or below the place from which it last came out. Then there is the *back-pricking-stitch* and the *fore-pricking-stitch*, in which the needle is first put entirely through, and then passed back again, so as to hold the cloth securely on each side. The *serging-stitch* is made by passing the needle through the cloth from the under to the upper piece, throwing the thread over the edges so as to keep them closely together: it is also used in joining selvages. The *cross-stitch* consists of two parallel rows of stitches, so placed that the stitch in the upper row may be opposite the space in the lower one, the thread passing from one stitch to the other in diagonal lines: it is used for keeping open the seams of such garments as require washing, and also from securing edges from ravelling out. In the *button-hole stitch*, the needle is first put through the cloth from the inner to the outer surface, and before it is drawn out, a twist is passed round the point, and when it is drawn out, a kind of loop or *purl* is formed at the top or edge of the opening. To increase the strength of this stitch, and to assist in making it true, a *bar* is formed on each side of the opening, before working the hole. This bar is made by passing the needle from one end of the opening to the other several times, upon which the hole is worked, the bar being kept as near the edges of the opening as possible. In the *hemming-stitch*, the needle is not inserted deeply, but in such a manner that the stitch is scarcely visible on the other side of the cloth. The *filling-stitch* is like the hemming, only in hemming, the point of the needle is directed away from the workman, but in filling it is directed towards him. This stitch is used for sewing on facings. *Stotting*, pronounced *stoating*, is the stitch used for joining pieces of cloth so as to conceal the join. The pieces are not laid one upon the other, as in back stitching, but are placed side by side with the edges carefully fitted, and the needle is passed half through the thickness of the cloth. The stitches must be kept as near the edge of the cloth as possible: the needle is put in on the nearer edge of the two, and not slanted, but put as straight-forward as possible. This stitch is used for joining the pieces of cloth for facings, collar linings, and other fillings up on the inner sides of garments, and also for preventing too much of the cloth from being taken up, if a back-stitched seam were made. *Rantering* is also intended to conceal a join: the seam is first made with a fore stitch, and over this the rantering stitch is made. Very fine silk thread is used, or twist, with one of the strands taken out, and a long and slender needle. *Fine drawing* resembles rantering, and is mostly used for closing places that have been torn. *Overcasting* is used to secure the edges of thin and loose fabrics from ravelling out. There is also a peculiar stitch required in making cloth buttons, but these are for the most part made by machinery, as described in our *Illustrations of Manufactures*. Indeed, machinery bids fair to supersede a large amount of the tailors' hand labour: already the *sewing machine*, as it is incorrectly called, is in extensive use for stitching the seams of trowsers and similar work. In Judkins' sewing machine, by turning a handle, 500 stitches are made per minute. There are two threads employed, one of which is carried in a shuttle, and the other taken from a reel and passed through the cloth by the point of the needle, so that when the latter is withdrawn from the cloth, both threads are locked together, forming a firm and durable stitch.

In making up a suit of clothes, the workman is guided by certain chalk marks made by the cutter-out, as for example, in the pieces required for a waistcoat, there may be two chalk lines, one running across to indicate where the pocket-holes are to be cut, and the other going down the front to mark the distance from the edge at which the buttons are to be put. All seams require to be well pressed with a hot iron, and projecting parts neatly pared, for which purpose the sleeve-board is useful. When the garment is finished, the glossiness produced by the iron should be wiped off, and the coat brushed.

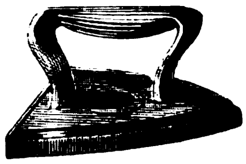

317. MEASURE.

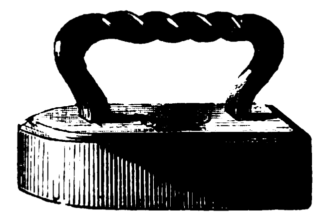

318. SLEEVE BOARD.

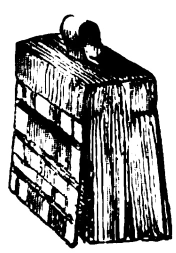

319. SHEARS.


320. WHISK.


321. IRON HOLDER.

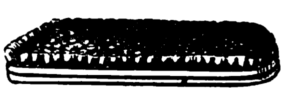

322. FLAT IRON.


323. GOOSE.

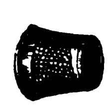

324. COAT PATTERN BOOK.

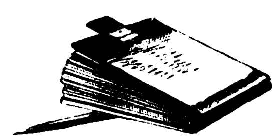

325. WORKSHOP.

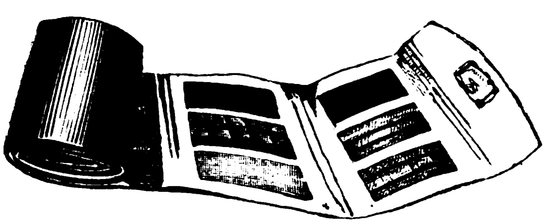

326. GOOSE STAND.

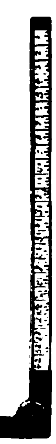

327. HARD BRUSH.

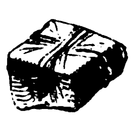

328. FRENCH CHALK.


329. THIMBLE.

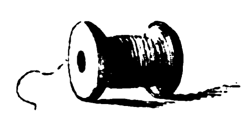

330. MEASURE BOOK.


331. TROWSERS PATTERN BOOK.


332. RULE.


333. WAX.


334. NEEDLE AND THREAD.


335. REEL.

XVI.—THE SHOEMAKER.

The trade which prepares coverings for the feet is much subdivided. Thus we have the *shoe-closer*, generally a woman, whose business it is to prepare the upper leathers of shoes; the *shoe-man*, who fixes the soles to the upper leathers; the *boot-closer*, who prepares the leg and *vamp* of the boot; the *boot-man*, who fastens on the soles; the *blocker;* the *clicker;* the *runner;* and the *cleaner*. For women's shoes there is the *binder*, who is a woman; but the shoes themselves belong to the *women's shoes maker*, to which belong the *sew-round man*, the maker of *women's welts*, and some others.

The shoemaker's tools and materials form collectively the *grindery*. This term originated in the circumstance that formerly the man whose business it was to sharpen the shoemaker's tools found it to his advantage to collect in his grindery or shop the hemp, the flax, the wax, the hairs, the tools, and stone rubbers used in the trade. The tools of one individual shoemaker form what is called his *kit*, and they consist of *pincers* (fig. 337), *nippers*, *hammer* (fig. 348), various kinds of *awls* (fig. 355), *seat* or *setting irons* (fig. 343), and other articles. The shoe-closer requires a slip of board to fit or prepare her work on, a pair of *clams* (fig. 339), or two tall nipping pieces of stave-like timber, which are held together between the knees; a block, or nearly half-round clump of wood, which is held on the left thigh by the *stirrup* (fig. 336), a *knife;* two differently sized *closing-awls;* and a *stabbing-awl;* two or three *seam-sets*, a *case of needles* called *short blunts;* a *thimble;* and some *silk twist;* while for the hem or whip on the linings, *common sewing silk*. Also some *paste*, contained in a horn (fig. 351), a little *flax* for the coarse or strong work; and *gum arabic* dissolved in ink or water. The seam is closed by joining the two shoe quarters and the vamp together, and also the back part of these quarters. The *flat* seam, or *outside* seam is employed, the *inside* seam being used on inferior work.

The lining is also done by women, that for the quarters being of some lively coloured roan or morocco, with abundant stitches. After the lining the *upper* has to be *set;* the *flat-seam-set*, or, if stabbed, the *stabbing-side-set*, is heated at a candle, and a solution of gum being rubbed on the seam, the set is briskly and forcibly pressed along the line of stitching. It thus becomes polished and hardened, and is ready for the maker or shoe-man. After the closing, the shoe goes through various operations, such as the *lasting* or tacking of the upper leather to the *in-sole*, the sewing in of the *welt*, the stitching to this welt of the *out*, or *top-sole*, the *building*, and sewing-down of the heel, and lastly, the *setting* or *taking-off*. After this the shoe has to be *rounded*, or pared round the quarters, and across the top of the vamp. It is then bound, and lastly, polished or cleaned up.

In making a boot, the *clicker*, or cutter, having given the proper form to the vamps, legs, &c., the *closer* does his work. The closing is the most delicate operation in the trade. The seam is made by means of waxed threads, to the ends of which are attached hairs or bristles for their ready insertion into the holes made by the awl. In what is called *stabbing* the portions of leather are stitched directly through, either in straight or curved lines. The work is held either in the clams or between the knees, and receives the awl at the right side piercing through to the left or inner side, from which the left-hand hair should be at once protruded, the right-hand hair being put in afterwards, and the stitch being then drawn smartly in. This is called *blind-stabbing*. The term has been explained by Mr. Devlin, in "The Shoemaker," published in Mr. Charles Knight's Guide to Trade. He says, "Quickly goes in the awl, and as quickly out again, but not before the hair from the fingers of the left hand has found the passage, without being at all directed by the sight, but literally in the dark, and hence the term *blind-stabbing*, the right-hand hair immediately following in the opposite course, the closed thumb and forefinger of either hand nipping at the moment the hairs from these different directions, and drawing the same as instantly out, at once completing the stitch." A proficient closer will, in half an hour, stab the four side rows and the two back rows of the counter of a boot, making about twenty stitches to the inch, the entire work averaging about thirty inches. Mr. Devlin says that he has made as many as sixty stitches in the inch.

The work next goes to the boot-man, who makes or attaches the sole. This is more difficult than in the case of the shoe. The lasting is more difficult; a *rand* is made to the heel, or what is called the *French seat*, and this with the *shank piece*, or strengthener between the inner and outer sole, which runs along the waist of the boot, are additions not to be found in the shoe.

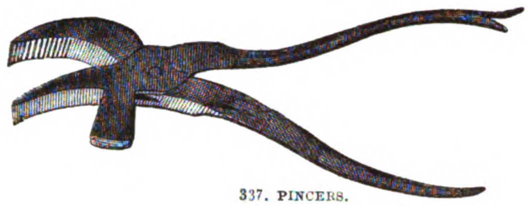
The master shoemaker or his clicker takes the required measures, chooses the materials, causes the Wellington fronts to be blocked, fits up the lasts, cuts out the work for the closer, prepares and sorts the sole or bottom stuff for the maker, examines the workmanship, and polishes up the boots.

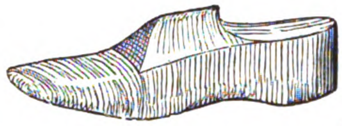
Women's common or welted shoes resemble men's. The man's and woman's single-soled shoes or *pumps* are also similar.

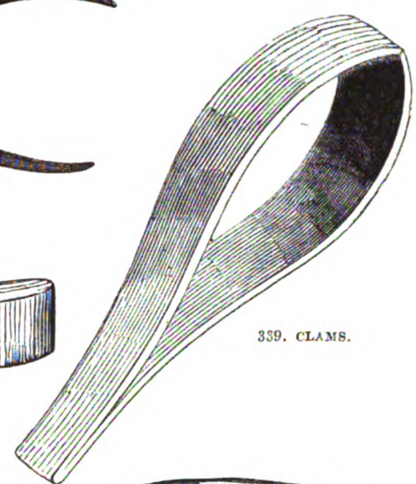
There are several finishing processes, such as *paring* by means of the *knife* (fig. 352), *rasping* with the *rasp*, fig. 350, and *scraping* with the edge of a piece of glass. The tool, fig. 341, is for setting up and polishing the fore-part stitch. The *jigger*, as it is called, is used with a little soap rubbed along the stitches. A solution of gum is also employed. The ridge left by the jigger is sometimes slightly filed from the sole towards the edge where the leather turns over a little, forming what is called the *crease*. This is rubbed with the *fore-part iron* (fig. 340), which forms it into a hard wire, and produces a firm, glossy edge. The *seat iron* (fig. 343) is used to set or harden the lower part of the heel.

The *glazing iron* (fig. 342) is also used for polishing the sole. The *lap-stone* (fig. 353) is a smooth stone, on which the sole leather is condensed and made more durable by hammering it with the broad face or pane of the hammer (fig. 348). The fine polish on the upper leather is produced by straining the shoe on a last (fig. 338), and rubbing it with the polishing stick (fig. 354), a good kind of blacking being previously applied.


336. STIRRUP.


337. PINCERS.


338. LAST.

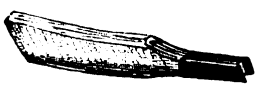

339. CLAMS.


340. FORE-PART IRON.

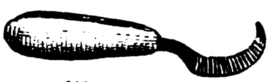

341. JIGGER IRON.


342. GLAZING IRON.


343. SEAT IRON.


344. BEVEL IRON

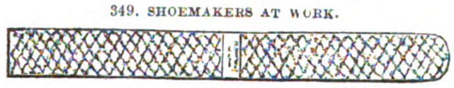

345. BREAKER.


346. SEAT FILE.


347. JIM CROW.


349. SHOEMAKERS AT WORK.

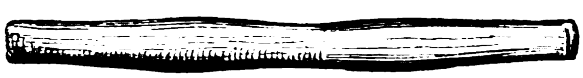

348. HAMMER.


350. RASP.


351. PASTE HORN.


352. KNIFE.


353. LAP STONE.


354. POLISHING STICK.


355. AWL.

XVII.—THE CABINET-MAKER AND UPHOLSTERER.

It is the business of the cabinet-maker and upholsterer to prepare the furniture of rooms, such as tables, chairs, drawers, &c., and most of the operations of preparing the wood are performed at a *bench* (fig. 371). This is made very strong, the joints being connected by means of screw-bolts and nuts. The surface is made flat and true, and there is a trough for holding small tools. One of the chief operations performed at this bench is the planing of wood, for which purpose the plank or other article is laid on the surface, and is prevented from slipping by means of the iron *bench-hook*, *h* (shown in a separate figure, 366). This has teeth which hold the wood, and prevent it from moving sideways; but as these teeth might injure a nearly-finished article, there is a square *wooden stop w* (shown separately, fig. 369); *i i* are other stops (see also fig. 370). All these stops fit in mortices, and can be placed at any required height, or depressed, so as to be flush with the bench. At the side of the bench are two *screws*, *s* and *s'*, which, with the *chop*, *c*, form a vice; the screw, *s*, simply presses the wood, and the screw, *s'*, is furnished with a piece, *g*, shown detached, called a *garter*, which goes into a groove in the neck of the screw, *s'*, so that when both screws are opened, the screw, *s'*, serves to bring the chop, *c*, outwards. The chops open many inches, and hold work by the sides or edges, so that small boxes, drawers, and other work can be held between them. The end-screw, *e*, draws out the sliding-piece, *p*, and serves to hold thin works, and also works by the two ends, and is useful in making grooves, rebates, and mouldings. The holes in front of the bench are for an iron stop, *i*, the face of which is slightly roughened, and there is a similar stop in *p*, so that on placing pieces between these two stops, they will be held securely by turning the screw, *e*. There is also an iron holdfast, *o*, the straight arm of which fits into a hole in the bench, and it is useful for holding squared pieces of wood, when making mortices or dove-tails: the work is fixed by a blow on the top at *o*, and is released by a blow at the back at *l*. There is a pin in one leg of the bench at *p*, for fitting into one of the holes in the same leg, for supporting the end of long boards, the other ends of which are fastened by the screws, *s*, *s'*.

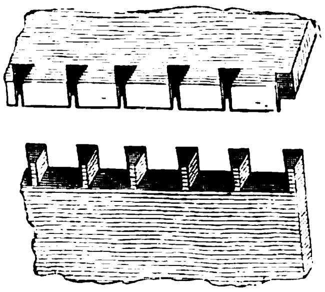
The planes in general use are the *jack-plane*, for coarse work, the *trying-plane*, for giving the work a better figure, and the *smoothing-plane*, for finishing the surface. The plane is furnished with a *toat* or *handle*, which is held in the right hand, the front being grasped with the left, and the body of the workman is pressed down on the work, so as to throw part of its weight on the plane. The best planes are furnished with a double iron (fig. 360), united by a screw, but the lower piece is alone used in cutting, the upper or *top-iron* assisting the ascent of the shavings. The *plane* (fig. 377)is a form in common use on the continent, the projecting handle or *horn* being held in the left hand, while the right is placed on the back of the stock. Grooves, mouldings, rebates, &c. are made by means of planes of the required form, so that the iron may cut out the wood as it moves along. (See fig. 368.)

Among the joints used by the cabinet-maker, none is more common than the *dove-tail*, fig. 358. Such joints are used for joining the ends of boards at right angles with each other, as in boxes, drawers, &c. In toys and common works, a kind of sham dove-tail is used, by planing the edges to be united, at an angle of 45°, slightly securing them by glue, and then making upon the angles with a back-saw, a few cuts, leaning alternately upwards and downwards: pieces of veneer are then glued and drawn into the notches. The work is then said to be *mitred and keyed*, and the whole is tolerably strong. Fig. 356 shows the separate parts of the common dove-tail joint, the lower board showing the pins, and the upper the dove-tails. In cabinet-work it is usual to make the dove-tails on the front or more exposed part of the work, and the pins are cut of only one fourth the size of the dove-tails, so that but little of the end wood may be seen. To produce close joints, nice work is required. The work is nicely set out or marked, and the cuts are made with the *dove-tail saw*, which is one of the numerous saws with backs to keep the blade straight. The wood between the dove-tail pins may be cut out with a *bow* or *turning-saw*, which is a small saw set in a frame also for the purpose of keeping it straight, and the spaces are pared out with the chisel, driven with the mallet. The pins are usually made first, and the dove-tails are marked from the pins. The gauge lines should be left in sight; so that the dove-tails may be a trifle too small, so as to compress the pins, and produce a close joint.

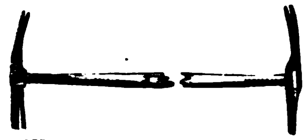
The cabinet-maker uses a variety of boring tools, the simplest of which is the *brad-awl* (fig. 372), and the *awl* (372*). The brad-awl is a cylindrical wire, with a chisel edge, but it is sometimes sharpened with three facets. The awl is square and sharp on all four edges, and gradually tapers off until near the point, when the sides meet more abruptly. Most of the boring tools used in carpentry are fluted to make way for the shavings, and they are sharpened in a variety of ways. The *gouge-bit* (fig. 361), also known as the *shell-bit* and *quill-bit*, is sharpened at the end like a gouge, and when turned round, it cuts the fibres round the margin of the whole, and removes the wood nearly in the form of a solid plug. The *spoon-bit*, (fig. 367) is usually bent up at the end, so as to make a taper point: it is in common use for making the holes for the wooden joints of tables, &c. The *auger-bit* (fig. 363) also known as the *nose-bit* and the *slit-nose-bit*, is slit up a small distance near the centre, and the larger piece at the end is then bent up nearly at right angles to the shaft, so as to act like a paring chisel. The *gimlet* (fig. 362) is also a fluted tool, ending in a pointed worm or screw, for drawing it into the wood while the chief part of the cutting is done between the angular corner between the worm and the shell. The latter gets full of wood, when the tool must be taken out to empty it. The *centre-bit* (fig. 364), of which three views are given, consists of three parts:—1, a centre, triangular point, or pin which serves as a guide; 2, a thin shearing point or *nicker*, for cutting through the fibres; and 3, a broad chisel edge or cutter, placed obliquely, for paring up the wood within the circle marked out by the point. There are a great many varieties of centre-bits: there are many boring-tools made with spiral stems, similar to the *twisted gimlet* (fig. 362), to enable the shavings to ascend the hollow worm, and thus save the trouble of withdrawing the bit so often. Of this kind is the *screw-auger*, fig. 365. There are an immense number of other tools which might be noticed, but we must refer the reader who desires to make their acquaintance, to the second volume of Holtzapffel's excellent work on "Turning and Mechanical Manipulation."

In the preparation of furniture, the taste of the artist may often be called into exercise, not only in promoting beauty of form, but in various carvings and inlayings. The French are distinguished for ornamental cabinet-work, especially for their *marqueterie* inlay, or the inlaying of woods of various tints in the form of flowers, ornaments, &c.; as also for their *buhl-work* (so called from M. de Boule, a French cabinet-maker of the reign of Louis XIV.), in which metals are inlaid on grounds of tortoise-shell or ebony. In some cases, ebony cabinets are inlaid with precious stones, and a variety of woods and metals surmounted with carved figures, with perspective recesses, and innumerable drawers, &c. We may also refer to the art of *veneering*, or the covering of a common wood, such as the surface of a deal table, with a thin slice of some beautiful and costly wood, so as apparently to convert the deal table into a mahogany one. Marqueterie work, when applied on a bolder scale to the production of floors, is called *parqueterie*, and when applied to the decoration of wall panelling, it is known as *tarsia-work*. Of late years, porcelain panels have been inlaid in furniture with good effect.

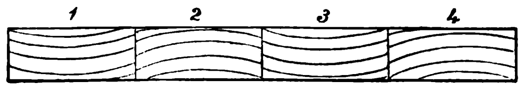
The work of the upholsterer usually follows, or is dependent, on that of the cabinet-maker, and a glance at the interior of his shop (fig. 376) will give an idea of the nature of his work.



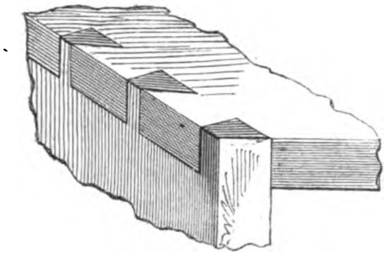
356. DOVE-TAILING.



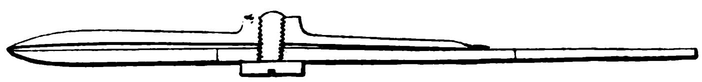
357. UPHOLSTERERS' HAMMERS.



359. JOINING WOOD TO PREVENT WARPING.



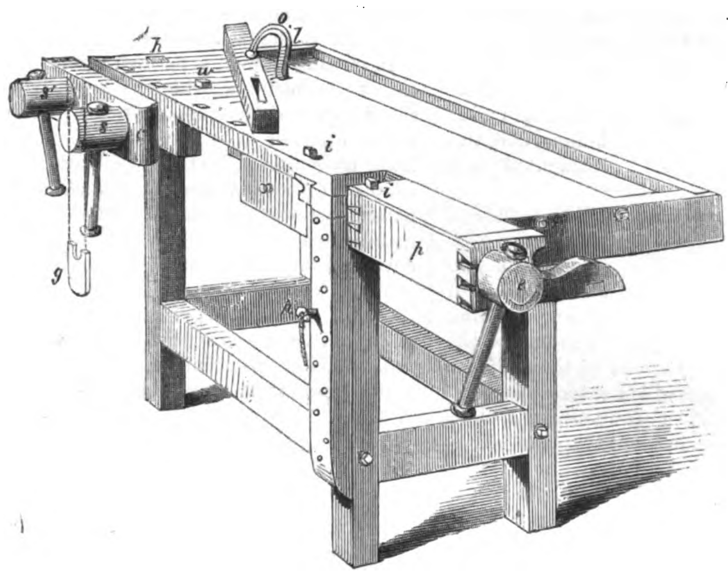
358. DOVE-TAIL JOINT.



360. PLANE IRON.

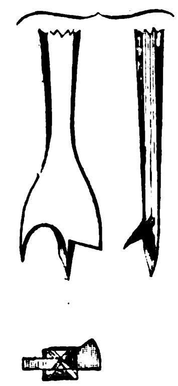
361. GOUGE-BIT.

362. TWISTED GIMLET.



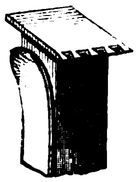
371. THE BENCH.

363. AUGER BIT.

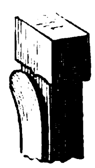


364. CENTRE BIT.

365. SCREW AUGER.

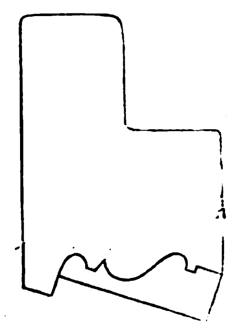


366. BENCH HOOK.

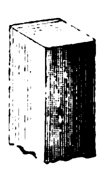


370. IRON STOP.

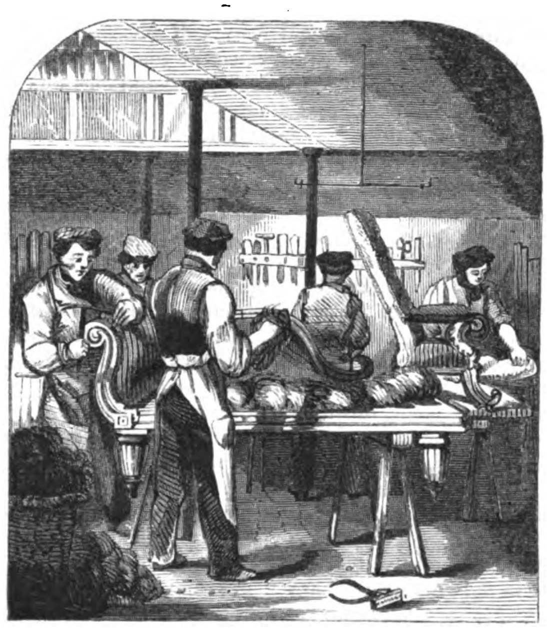
367. SPOON BIT.



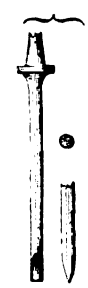
368. MOULDING PLANE.



369. STOP.



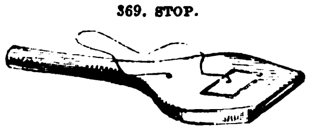
376. UPHOLSTERER'S SHOP.



372. BRAD-AWL.

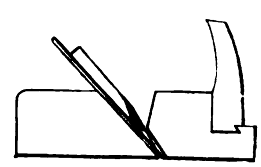
*372. AWL.

373. STRAINER



374. WEB STRAINER.

375. SQUARE.



377. PLANE.

XVIII.—THE TURNER.

THE business of the turner is to shape wood, metal, and other hard substances, into round or oval figures, by means of a machine called a *lathe*. The art of turning is of very ancient date, and the potter's wheel, probably, the earliest form of lathe. But in this case the axis is vertical, instead of being horizontal. There are few machines more useful than the lathe, for by its means various parts of other engines and machines, and even tools, are produced. Indeed, nearly all solid objects in wood and metal, in which the circle or any of its modifications can be seen, are thus produced. In turning, the work is usually put into the lathe, and made to revolve with a circular motion about a fixed line or axis; it is worked to the intended form, by means of edge-tools presented to it, and held down upon a fixed rest. The projecting parts of the work are thus brought up against the cutting edge, and are cut off, whereby the outer surface is so reduced as to be at an equal distance from the axis of motion, and thus it has a circular figure. If the axis be made moveable during the revolution of the work, we may have *oval* and *rose-engine* turning. The work may be also turned hollow, and the outer surface may be fluted or grooved, and ornamented in a variety of ways.

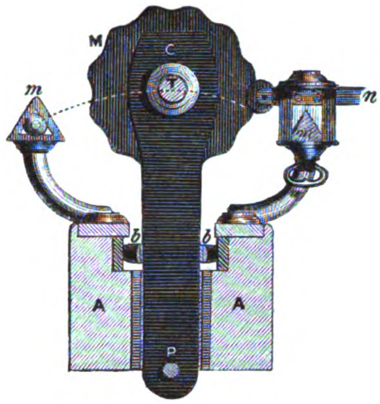
There are various descriptions of lathe, but it will be sufficient in this place to describe the *spindle* or *mandrel-lathe*, fig. 382. The uprights, *A A*, support the bed, *B*, which consists of two bars of iron, with an intervening space. Attached to the bed is a cast-iron frame, *C D*, for supporting the spindle or mandrel, *a b*. *E*, called the *back-puppet*, is used to support one end of the work, *G*, while the other end is fixed to the end of the mandrel, and is turned round by it; *E* has a pin which enters the work, and the screw, *e*, pushes it forward, while a clamp-screw, *E*, binds the screw and adjusts it. That puppet is secured to the bed by a tenon which enters the groove, and is secured by a nut *f*: but when this is loosened, the puppet can be slid along the bed, so as to be adjusted to the length of the work. The neck of the mandrel projects beyond the collar, and is furnished with a screw for receiving various pieces called *chucks*, each chuck being adapted to hold a different piece of work. The other end of the mandrel is supported by a point, or in a collar. When made with a point, it is received by the end of a screw tapped through *D*, by turning which, the mandril can be adjusted. Motion is given to the mandrel by means of a catgut band, passing round the pulley, *h*, and the large iron foot-wheel, *H*, attached to the axis, *I*. This axis has a crank in the middle, which is united by an iron link, *K*, to the treadle, *L*, which is fixed by three rails to an axis, *M*, on which the treadle moves. The lathe is set in motion by moving the wheel by hand, until the crank just passes over the highest point, when the motion can be continued by the foot. Attached to the bed is a rest, *N*, for holding the tools; it is secured by a nut, *K*, capable of being adjusted at pleasure. In turning cones or similar work, the edge of the rest is inclined to the axis of the work. Rests are made of different sizes, to suit different kinds of work: there is also a circular rest, which enables the turner to ornament balls and other round objects.

The turner uses a variety of gouges and chisels, some of which are represented in the figures. The gouges are first employed for roughing out and forming the work, and the chisels for smoothing and reducing it to the required form. The gouge is formed nearly half round to an edge, as in fig. 385, and the two extreme ends of this edge are sloped off, so that there may be no corners to catch in rough wood. In turning soft wood, the blade of the gouge is considerably inclined, as in fig. 385, but for hard wood a different kind of tool is employed, as in fig. 386, and is much less inclined. Other kinds of tools are shown in the figures, as at 387, for inside work, 394, for scooping out, and 392, for cutting screws, &c. Some of the tools represented are used in metal turning. For turning soft wood, the chisel is usually ground with a bevel on either side; but for hard woods, ivory, and bone, the cutting edges are bevelled only on one side, and the angle of the edge is obtuse. The turner also uses *calipers*, for measuring his work as it proceeds, and also *milling-tools*, or small wheels cut to a pattern, which, being pressed against the work while revolving, impresses a pattern on it. There are also various forms of chuck for holding the work, such as the *cup-chuck* (fig. 388), the chuck holding a centre-bit (fig. 389), and where great accuracy is required, the chuck (fig. 393), which is screwed to the mandrel, while a projecting steel point, exactly in the centre line, receives the work, and holds it between it and the point at the back centre.

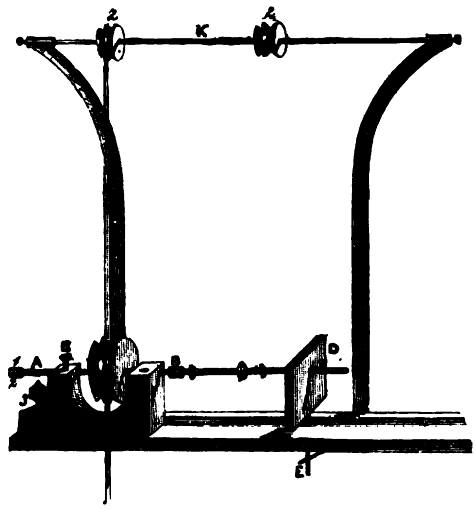
In cutting screws, a pattern screw, *a* (fig. 382), is fixed at the end of the mandrel, which is arranged so as to move endways; the distance of the threads in the pattern corresponds with the screw intended to be cut upon the work, which is fixed in the lathe by a chuck. At *n*, is a piece of brass cut with threads adapted to the pattern-screw, and being drawn up against the pattern-screw, works into its threads, and in so doing, makes the mandrel move endways with a screwing motion, so that if a cutting-tool be held steadily to the work, it will cut a spiral channel or screw upon it. In cutting screws *flying*, as it is called, the tool, fig. 392, is applied to the work, and moved along endways, so that the work, in turning round, will receive a spiral cut, but this is not so accurate a method as the former. Outside and inside screw-tools are used, as in fitting the screw top to a turned box, &c.

By using eccentric, oval, or elliptic chucks, a great variety of geometric patterns may be produced. Some lathes are furnished with what is called an *over-head motion*, fig. 379, and it is useful for ornamenting the sides, edges, or curved surfaces of work, but in such case it is the tool which revolves rapidly, and cuts the patterns, while the work remains fixed. The iron frame, fig. 379, is attached to the bench of the lathe, and in the front, above, is a spindle working in nuts, 1, 1, and attached to the spindle are a couple of wheels, 2, 2, the one on the left, situate over the fly-wheel of the lathe by which it is turned, while the other slips backwards and forwards, to adapt itself to the work, the ordinary catgut is removed from the fly-wheel, and a long one is passed over it, and over the small wheel, No. 2. The cutter is held in a slide-rest, and the other small wheel, No. 2, is brought over it and a catgut connects it with the small brass wheel, *B*, of the cutter. A metal wheel, graduated into 360 parts, each marked by a small hole, is used to regulate the patterns. The wheel is kept steady by a small steel key, *h*, slipped into a brass knob, while the other pointed end enters one of the small holes, and the work remains fixed, until the key is moved into another hole.

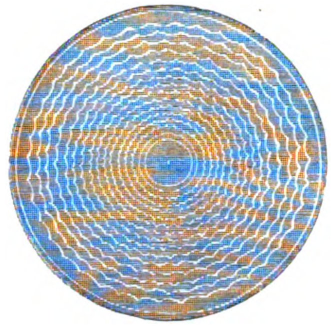
In rose-engine turning, or in the production of rosettes, such as fig. 380, the centre of the circle in which the work revolves, is made to oscillate with a slight motion while the tool remains fixed; for which purpose the mandrel, *N*, fig. 378, is furnished with a variety of rosettes of different patterns, some of which are scolloped out as in the figure, the number of scollops varying from 12 to 144. The work is held in a chuck attached to the end of the mandril, *T*, and the standards which support the mandril are not fixed to the bed, but descend between the cheeks. The work is fixed in a chuck at the end of the mandrel, and the tool is held by a slide-rest, while attached to the mandrel is a metal rosette, for giving the required oscillating motion. The rosette is acted on by a small roller at the end of the piece,



378. ROSE ENGINE.

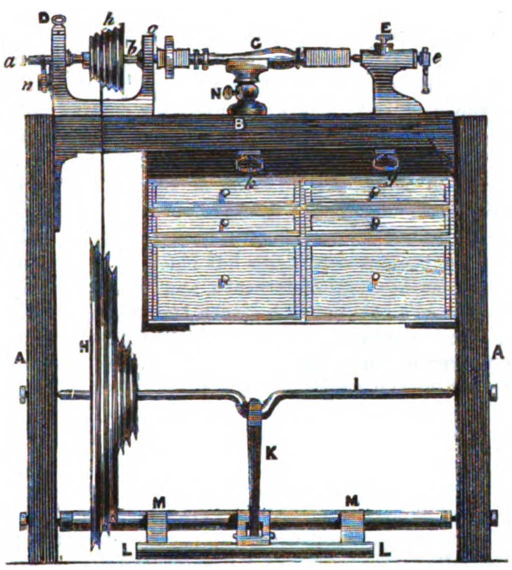


379. OVER-HEAD MOTION.

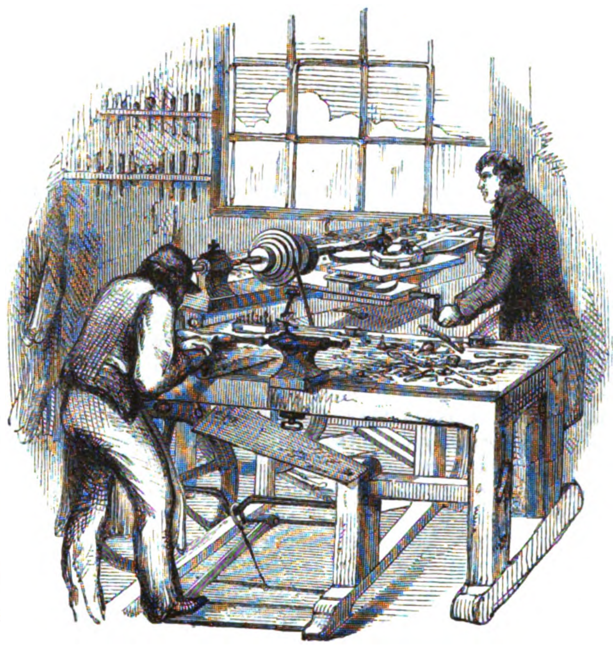


380. THE ROSE.

381. SHAPING TOOL.

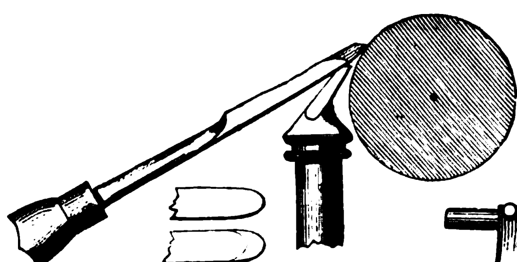


382. SPINDLE OR MANDREL LATHE.

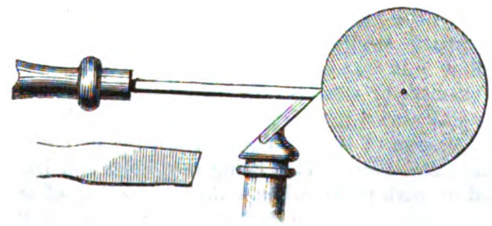


383. TURNERS AT WORK.

384. SMALL GOUGE.

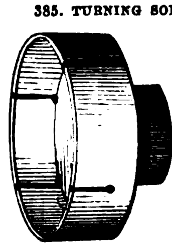


385. TURNING SOFT WOOD.

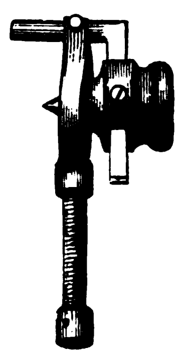


386. TURNING HARD WOOD.

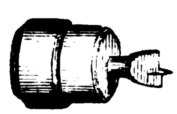
387. INSIDE TOOL.



388. CUP CHUCK.



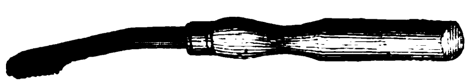
389. DOG AND CARRIER CHUCK.



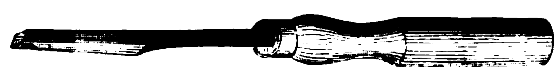
390. CHUCK AND CENTRE BIT.

391. CENTRE BIT.

392. SQUARE TOOL.



393. SCREW TOOL.



394. SCOOPING OUT TOOL.

n, which is supported by a triangular bar, *m*. As the mandril revolves, the eminences and depressions of the rosette adjust themselves to the roller, and produce the oscillating motion of the mandril, while the springs, *b b*, restore the mandril to a vertical position, when disturbed therefrom by an indentation of the rose. Fig. 383 represents turners at work, the one on the left, in the ordinary manner, and the one on the right is managing the slide-rest, which holds the tool for more accurate work.

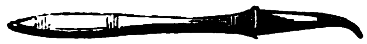
XIX.—THE PICTURE-FRAME GILDER.

THE man who prepares picture and looking-glass frames, usually calls himself a "carver and gilder," by which it is understood, that he prepares, or causes to be prepared, the artistic work of the frame, as well as laying on the gold by which it is decorated, or supplying the plate-glass of the mirror, and the silvering at the back, by which it is made reflective. The fact is, that a number of trades are concerned in carving and gilding. It is rarely that an artist designs, still less executes, the carved work of a frame, on account of the costliness of artistic work by hand. Manufacturers are furnished with a set of moulds, by which they produce, by casting, any number of ornaments in plaster, composition, *carton-pierre*, *papier-maché*, &c. or the ornaments may be stamped in leather, embossed, coated with silver-leaf, and varnished with lacquer; and such has been the demand for the latter style of ornament, that the hydraulic press has been employed to produce it. A large number of ornaments are also executed by a machine in which a series of drills are pointed from a model, so that Gothic oak screens, dead game, foliage, &c. can be produced with great economy, the last touches being given by hand. All this is very different from the wood carving, which was formerly executed by real artists, such as Gibbons, a single work of whom we have known to produce upwards of 200 guineas. The gilder therefore has no choice but to purchase his ornaments ready made, and attach them to a plain frame, or to purchase the frame already ornamented in the rough, and finish it by gilding. In the same way the carver purchases the plate-glass properly silvered from the wholesale dealer, and mounts it in a frame suited to the taste and means of the purchaser. There are various articles of furniture which require the intervention of the gilder, such as window-cornices, gilt bordering for the top and bottom of a room, tripod-stands, flower-baskets, candelabra, &c. In some cases, as in the frames for prints, very little gilding is used, for, with the exception of a narrow beading, the whole is made of some ornamental wood.

The simplest gilt frame, such as a bevelled flat frame, may furnish an example of what is called *burnish-gilding*. The joiner supplies the gilder with moulding, in lengths of twelve feet, and the gilder gives one of these lengths a *priming* of hot size and whiting, called *thin white*. This being dry, holes and irregularities are filled up with putty, when a thicker coating of size and whiting called *thick whiting* is laid on, and to prevent the fine hollows from being filled up, the edge of a crook or chisel is drawn along them. Other coatings are also laid on, after which the opening tools are again used, and a smooth surface is produced by means of one of the burnishers, consisting of hard smooth stones, mounted in handles, as in figs. 398 to 401. The work is next trimmed at the back and edges, and then smoothed by pumice-stone properly shaped, the work being wetted from time to time. Much of the success of the burnished gilding depends upon having a good smooth foundation of whiting. The moulding is next dried, rubbed down with sand-paper, and then *gold-sized*, gold-size being a compound of pipe clay, red chalk, black-lead, suet, and bullock's blood. This is laid on with a soft hog's-hair brush, or with a large camel's-hair pencil, from four to eight coats being used. The whole is next smoothed by washing with a soft sponge and water, and the parts which are to be *matt* or *dead* are polished with woollen cloth, while the parts to be burnished receive another coating of gold size. All is now ready for *gilding*, the tools for the purpose consisting of a *cushion* (fig. 414), covered with leather, with a parchment rim round a portion of its sides, to prevent the wind from blowing away the gold leaf; of a knife used for cutting gold (fig. 402), peculiar in shape, and of a tool used for laying on the gold, which is a kind of camel's-hair brush (fig. 406), called a *tip*. The gold is in leaves so thin, that upwards of 290,000 of them would be required to make up the thickness of an inch. These are contained between the leaves of a book (fig. 416), and the gilder, supporting the cushion on his left hand, by inserting his thumb through a leather loop underneath, and holding the tip, the knife, and the camel's-hair pencil between the fingers of the same hand, blows out the leaves of gold from the book on his cushion, and then taking up one leaf with his knife, he lays it down on the front part of the cushion, and spreads it out by gently blowing on it. Then taking his knife, he divides the leaf into a number of parts or *lays*, and wetting a portion of the moulding with a camel's-hair pencil, he takes his tip in his right hand, lays it on the slip of gold which adheres slightly to the hairs, takes it up, and places it on the moulding, blows forcibly upon it to expel some of the water from below, and presses down any parts which do not adhere by means of a dry camel's-hair pencil. In this way he proceeds until all the lays into which the moulding has been divided, have been covered. When properly dry, a flint or agate burnisher is passed over those parts which are to be burnished, and those parts which are not burnished are *weak-sized*, or wetted with water containing a small quantity of size. When dry, the gold is wiped with cotton wool, and faulty places are repaired with gold leaf, and the work is wetted with *finishing size*.

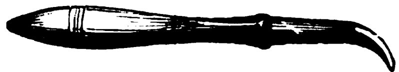
The frame-maker, who is distinct from the gilder, now takes the moulding and cuts it up into pieces of the required length, and makes these pieces up into a frame. In cutting up the moulding, the saw is guided by a *mitre-box*, which consists of two raised ledges of wood, with oblique cuts in them; the moulding is placed between these ledges, and a back-saw being introduced into the cuts, the moulding is accurately divided by oblique cuts, and these surfaces being smoothed by a plane, are fixed by means of glue and nails. Much skill is required to produce a frame, without soiling or injuring the gold. The gilder now takes the frame again, stops up the nail-holes with putty, paints the outside yellow, and if any small light ornaments are required for the corners, attaches them already gilt by means of weak glue. In gilding a richly-ornamented frame, the processes vary somewhat, but the above description will sufficiently indicate the nature of the gilder's work.

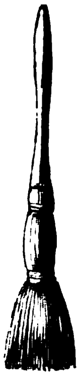

397. PUTTY KNIFE.

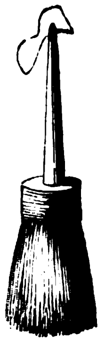

398. MINIATURE BURNISHER.


399. BURNISHER. No. 1.


400. BURNISHER. No. 2.

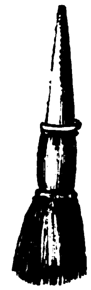

401. BURNISHER. No. 3.

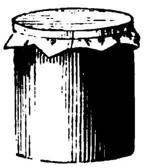

395. BADGER TOOL.

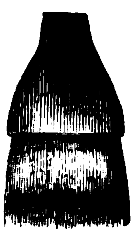

396. DUSTER.


402. KNIFE.

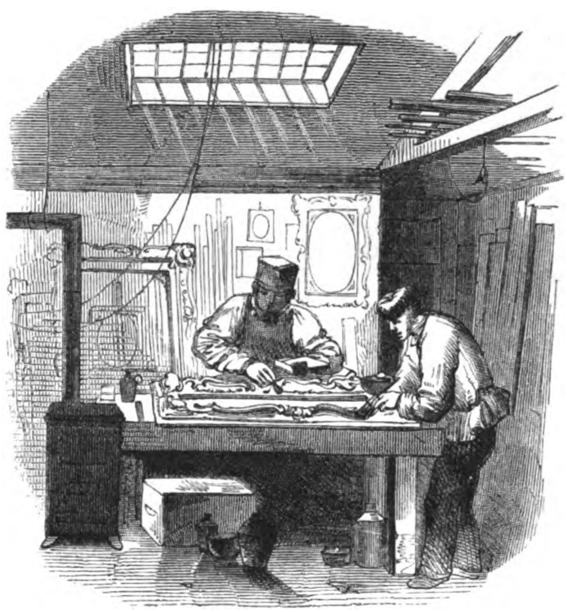

403. SKEWING BRUSH.

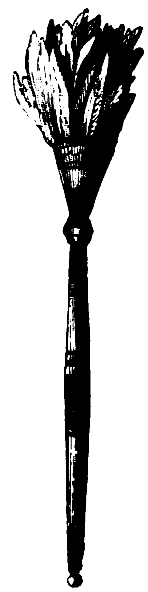

404. PUTTER-DOWN.


405. SIZE POT.


406. TIP.


407. RULE.

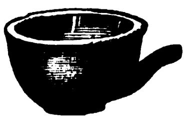

408. WORKSHOP.

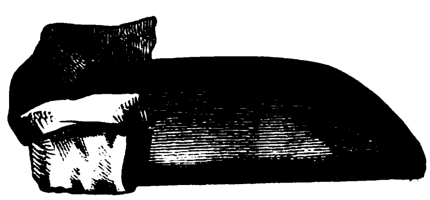

409. FEATHER DUSTER.


410. GOLD SIZE POT.

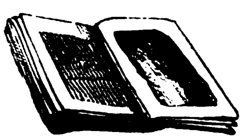

411. SIZE.


412. WHITING.

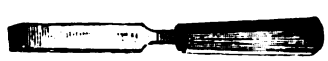

413. PIPKIN.

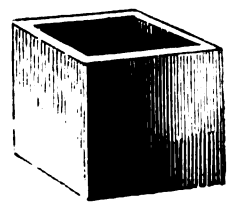

414. CUSHION.


415. PAN.


416. GOLD BOOK.


417. SMALL PENCIL.


418. CHISEL.


419. GOLD LEAF BOX.

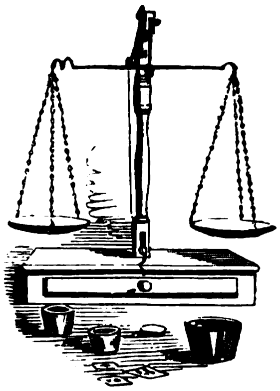
XX.—THE GOLDBEATER.

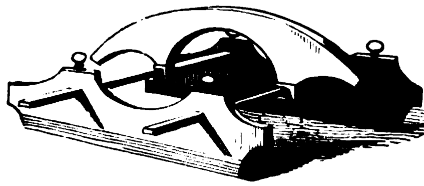
The preparation of the gold leaf, as used by the gilder, is the business of the goldbeater, who, taking advantage of the wonderful malleability or powers of extension possessed by the precious metal, beats it out into such thin leaves that 290,000 of them would be required to make up the thickness of an inch. That such is the case may be proved by a little calculation. A cube of gold, weighing one ounce, would measure on each of its sides five-twelfths of an inch, and would cover a space of little more than one-sixth of a square inch. Now the goldbeater hammers out this cube of gold until it covers 146 square feet, and, in order to extend it from a surface of five-twelfths of an inch square to one of 146 square feet, its thickness must be reduced from five-twelfths of an inch to the 290,636th part of an inch. Gold is often beaten much thinner than this; even to the 367,650th of an inch, or about 1,200 times thinner than ordinary printing paper; but this is not the limit of malleability, although there are practical difficulties in the way of further reduction.

The goldbeater uses pure gold mixed with various proportions of silver or copper, to obtain different *colours*, as he calls them, and of these there are about thirteen, namely: *fine gold, red, pale red, extra deep, deep, orange, lemon, deep pale gold, pale, pale pale, deep party, party,* and *white*. The deeper colours are alloyed with copper, the middle colours with silver and copper, and the paler golds with silver only. The metals are fused together in a crucible, and cast into a flat, oblong ingot, one and a half inch long, three quarters of an inch wide, and three-sixteenths of an inch thick. This ingot is flattened out into a ribbon by being passed repeatedly between two rollers of polished steel, until it is spread out to a surface of 960 square inches of the thickness of rather more than $\frac{1}{800}$th of an inch. The ribbon is annealed or softened by means of heat, and is carefully marked out by compasses (fig. 422) into square inches; and 150 of these are placed between leaves of a tough paper of peculiar make, the packet of which, called a *cutch* (fig. 429), is inclosed in a parchment case open at both ends, and this in a second case, so as to cover the edges left exposed by the first. This packet is then beaten for 20 minutes with a 17-lb. hammer (fig. 424), on a smooth block of marble well supported from below, and surrounded on three sides by a raised ledge of oak: the front edge, which is open, is furnished with a leathern apron for catching any fragments of gold that may escape in the after operations. The cutch is so elastic that the hammer bounds off from it, and lightens the labour of the beater, who turns the packet over from time to time, to equalize the force, and occasionally bends it to and fro, to prevent the gold from sticking to the vellum. The packet is also opened from time to time, for the purpose of re-arranging the squares of gold, and the beating is continued until the one-inch squares are spread out into four-inch squares. The packet is now opened, and being held at one corner by the *span-tongs* (fig. 428), each piece of gold is removed, placed on a cushion, and cut into four pieces by means of a knife (fig. 434). In this way the 150 pieces become 600, and these are put between the leaves of a *tool*, made of goldbeaters' skin, called a *shoder*. This is inclosed in parchment cases, and beaten for 2 hours with a 9-lb. hammer (fig. 425), until the squares of gold are spread out nearly to the size of the skin, when the leaves of gold are again divided into four, and each quarter is placed between two membranes. The gold is now divided by means of the smooth edge of a strip of cane (fig. 437), since it has a tendency to adhere to a knife. The squares of gold, now 2,400 in number, are separated into three parcels of 800 each, and each parcel is made up in what is called a *mould* of goldbeaters' skin and beaten as before, when the squares again expand nearly to the size of the skin, and the process of beating is considered at an end. This last beating requires skill. During the first hour the hammer is directed chiefly on the centre of the mould. This causes the edges of the leaves to crack, but they unite again when beaten. During the second hour, when the gold is the 150,000th of an inch in thickness, it allows the light to pass through. If the gold be pure, or but slightly alloyed, the transmitted light is of a green colour; but pale violet if highly alloyed with silver. The mould is beaten during 4 hours with a 7-lb. hammer. The thin leaves are then taken up one at a time, by means of wooden pincers (fig. 436), placed on a cushion, and blown out flat by the mouth. The ragged edges are cut off by means of the tool (fig. 421), called a *waggon*, consisting of edges of cane mounted in a frame, the sides of which are $3\frac{1}{4}$ inches apart; there is a handle in the middle. In this way the dimensions of the leaves are reduced to about three and a quarter inches square. Twenty-five leaves are placed between the folds of a paper-book (fig. 439), the surfaces of which have been previously rubbed with red chalk to prevent the gold from adhering. As the book is being filled a leaden weight is kept at one corner of the filled portion to prevent the leaves from being blown up, and as the books are filled they are placed in a pile with the weight (fig. 423) upon them.

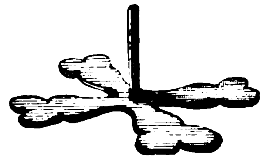
Steam machinery has been proposed and partially introduced for goldbeating, but this, we are told, has proved a failure. Silver and copper-leaf are prepared somewhat after the same manner as gold-leaf. Copper is much less malleable than gold, and silver-leaf is thicker on account of the less density of the metal; but calculated by weight, it does not appear that gold is more malleable than silver. The silver-leaf, however, which is used for silvering letters on omnibuses, &c., is really gold largely alloyed with silver. Pure silver-leaf would be liable to tarnish. There are other metals, such as platinum, palladium, aluminium, lead, zinc, cadmium, and tin, which admit of being beaten out into thin leaves. What is called *dentists' gold*, or the gold used for stopping teeth, is the gold beaten out from the ingot, then divided, and beaten out once again.

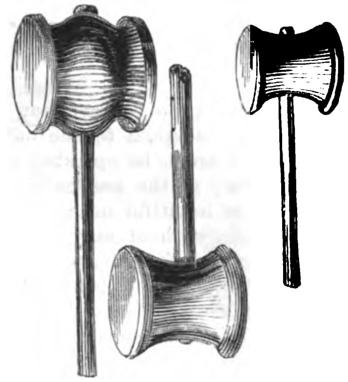
What is called *goldbeaters' skin*, is the serous membrane separated from the intestinal tube of the ox, and sometimes of other animals: it is spread out in the frame (fig. 443), (see also fig. 431,) scoured with pumice (fig. 432), made thin by being beaten with a hammer, and prepared with solutions of alum, isinglass, white of egg, &c. so as to resist putrefaction. A mould of skins contains 850 leaves, $5\frac{1}{8}$ inches square (each leaf being double), and nine-sixteenths of an inch thick, to produce which requires the slaughter of 500 oxen. A mould of skins costs £10, but it may be used during several months; and when the leaves are too thin or too weak for use, their flexibility may be restored by placing them between leaves of white paper, moistening them with vinegar, loading them with weights, and leaving them for a few hours. They are then beaten for a number of hours between leaves of paper or parchment, after which, to prevent the adhesion of the gold to the surface of the skin, they are rubbed over with calcined fibrous gypsum in powder, and are again fit for use. The powder is called *brime*; it is passed through the *sieve* (fig. 427), and is rubbed on with the *hare's-foot* (fig. 438). The dryness of the cutch, shoder, and mould are of importance; to insure which, they are hot-pressed in the iron *press* (fig. 433), every time they are used. In frosty weather the tools may become over dry, and then the lustre of the gold becomes dimmed and spreads slowly under the hammer. If the cutch or shoder be damp, the gold will become *hollow*, or *sieve-like*; that is, it will be pierced with numerous microscopic holes, and in the moulds will pass into a pulverulent state. The *rasp-knife* (fig. 441) is used for trimming the edges of the mould. The waste fragments of gold and the cuttings of the leaves are melted down into a globule of gold.

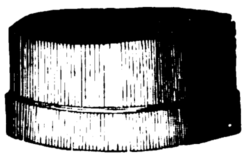

420. BALANCE.

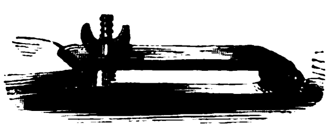

421. WAGGON.

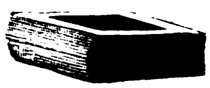

422. COMPASSES.


423. CROSS LEAD.


424, 425, 426. CUTCH, SHODER, AND MOULD HAMMERS.


427. SIEVE.

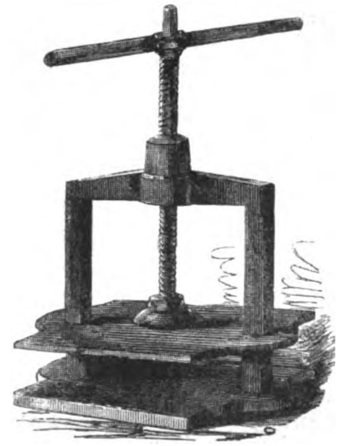

428. SPAN TONGS.

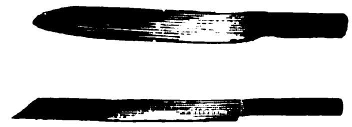

429. CUTCH.

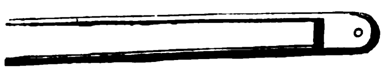

430. MOULD.

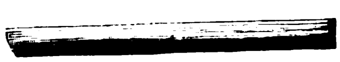

431. FILLING FRAMES.


432. PUMICING.


433. PRESS.


434, 435. SKEWING KNIVES.


436. PINCERS.

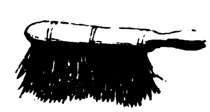

437. REED.

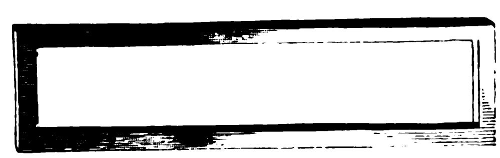

438. HARE'S FOOT.


439. GOLD LEAF BOOK.


440. GOLDBEATERS AT WORK.


441. RASP.


442. BRUSH.


443. FRAME.

XXI.—THE GOLD AND SILVER SMITH.

It is interesting to observe how well the processes of the Useful Arts are adapted to the nature and properties of the materials which are to be operated on. The ductility and malleability of many of the metals allow of their being wrought into a variety of beautiful and useful forms, such as deep vessels in common use, without any seam or join. In this way are formed tea-pots, coffee-pots, covers of cups and vessels, extinguishers, thimbles, the bell-mouths of certain musical instruments, &c. There are three methods adopted by the gold and silver smith for producing such articles. The first is called *spinning*, or *burnishing to form*, and is performed rapidly at a lathe. The second is *raising* by means of a hammer; and the third is *pressing* between dies. As an example of spinning, we may describe the method of forming the body of a tea-pot out of a flat disk of metal. The disk *d d* (fig. 448) is held by the fixed centre screw *s*, of the lathe, between two flat surfaces of wood *w w*, one of which, *m*, has the form of the lower part of a tea-pot. Now, it will be evident that as the lathe spins round, the mould *m*, the disk *d d*, and the piece of wood *w*, would all revolve with it. The workman now takes a burnisher *b*, and resting it against a pin in the lathe-rest, applies it to the metal near the centre, while at the opposite side is held a wooden rod *r*, to support the edge. In this way, the metal is rapidly bent or suaged into the form No. 2, and then into Nos. 3 and 4, so as to fit upon the block *m*. The latter is now removed, and its place is supplied by a smaller block *c*, of the same size as the mouth of the intended tea-pot. A burnisher, with its surface slightly greased, is used, together with a hooked stick *h*, for forcing the metal gradually inwards to the forms shown at 5, 6, 7, and also for curling up the hollow bead which stiffens the mouth of the finished vessel, No. 9. In some cases, the mould is of the shape of the finished vessel, and can be taken to pieces in order to be removed.

In raising by means of the hammer, the blows are applied in circles, much in the same manner as the burnisher in spinning, so as to produce the effect by gradual and continued pressure. The metal disk must be of such a size and thickness as to produce the intended article by raising, without leaving any excess of metal to be cut off, or any deficiency to be supplied, and the blows of the hammer must be so managed as to give the finished work the same thickness throughout. Such works as jelly moulds, where the raising is considerable, are done by the hammer; but works in less relief, and required in considerable numbers, are produced by means of dies. But here the work must be gradual, or the metal will be cut and rent. The method of arranging the dies is shown in figs. 447, 455, and the method of working has already been described in our *Illustrations of Manufactures* (figs. 499, 511, 513, &c.). The raising by means of dies must also be gradually brought about, and this is done by placing a number of sheets of metal between the two parts of the die, and after every blow removing one piece from the bottom, and adding a fresh plate at the top. In this way, the plates descend and gradually accommodate themselves to the figure of the die. The pieces are finished by being struck singly between corresponding dies. As the work proceeds, the metal must be annealed by means of heat. Thimbles are raised in five or six blows, between as many pairs of conical dies, which gradually increase in height.

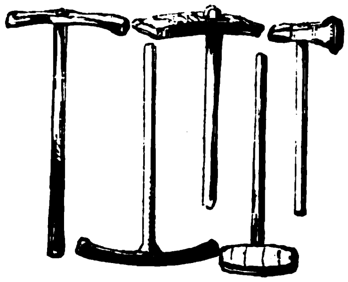
A number of ornamental details, such as escutcheons, concave and convex flutings, &c., are added to the vessel after it has been raised. An ingenious method of executing this part of the work is by means of a *snarling-iron*, *s* fig. 449, one end of which is secured in a vice *v*, and the other end *e* is turned up so as to reach any part of the inside of the vessel. The work is held firmly in the hands with the part to be raised or set out over the end *e*, when the snarling-iron is struck by an assistant with a hammer, and the reaction gives a blow within the vessel, the effect of which is to throw out the metal in the form of the end of the tool. When the ornaments have been snarled up, the vessel is filled with a melted composition of pitch and brick-dust, to serve as a support in the operation of *chasing* (fig. 450), and leave both hands of the workman at liberty. The work is then gone over with a punch *t* and a hammer, or with one of the gravers shown in fig. 446. The punches, or chasing tools, are usually counterpart forms of the snarled up parts, and with these the work is corrected and made uniform.

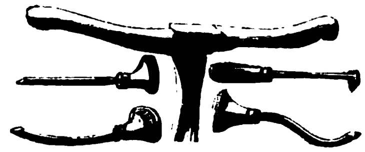
The gold and silver smith uses various forms of hammer (figs. 445 and 451), and irons of different shapes (figs. 444, 451, 453). The furnace for melting his metals and alloys (fig. 458) resembles the brass furnace described in the *Illustrations of Manufactures*, fig. 494. The polishing of silversmiths' work is done first with pumice-stone and water, then with Ayr-stone and water, thirdly, with a revolving brush with rotten-stone and oil (fig. 457), next with an old black worsted stocking with oil and rotten-stone, and it is finished with the naked hand, an operation in which women succeed better than men. But there is considerable difference even among women, a peculiar texture and condition of the skin being required for the purpose. The deep black lustre of silver is given by means of very fine rouge applied with the hand, for which purpose the skin should be soft and slightly moist, so that the powder may become attached to the hand, and there may be a certain amount of adhesion between the hand and the work. A dry hand becomes hard and horny and is apt to scratch the work, and a very moist hand becomes too slippery. The corners and edges of the work are usually burnished with a steel burnisher moistened with soap and water.

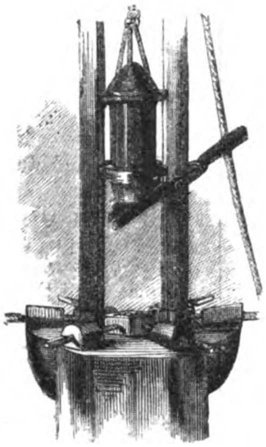
Some kinds of silversmiths' work are pierced and finished with the graver. The pattern is first drawn upon the article, pierced with a breast drill, and then cut out with a piercing saw, which is a fine frame saw, tightened somewhat after the manner of a violin bow.

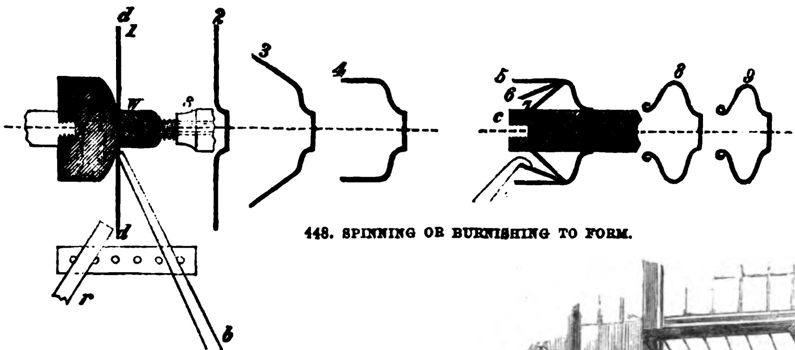
Gold plate is made of gold more or less alloyed with silver and copper. The purity of gold is expressed by the terms 22, 18, 16 *carats*. The pound troy is supposed to be divided into 24 parts, and could gold be obtained absolutely pure, it would be called 24 *carats fine*. The *old standard gold* of our currency is called *fine*, and consists of 22 parts gold and 2 of copper. The *new standard* for watch cases, &c. is 18 carats fine gold, and 6 of alloy. Gold inferior to 18 carats is rejected at Goldsmiths' Hall. It is then described by its commercial value, as 60 or 40 *shilling* gold, &c. The alloy may be of silver, which gives a green colour, or entirely of copper for a red colour, but the two metals are usually mixed.


444. BLOCKING BLOCK AND HORSES.

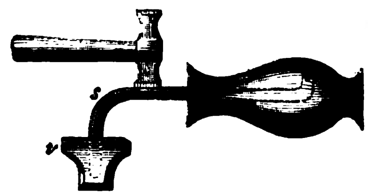

445. HAMMERS.


446. GRAVERS AND HORSE.

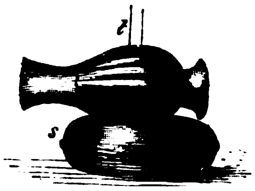

447. THE DROP DOWN.



448. SPINNING OR BURNISHING TO FORM.

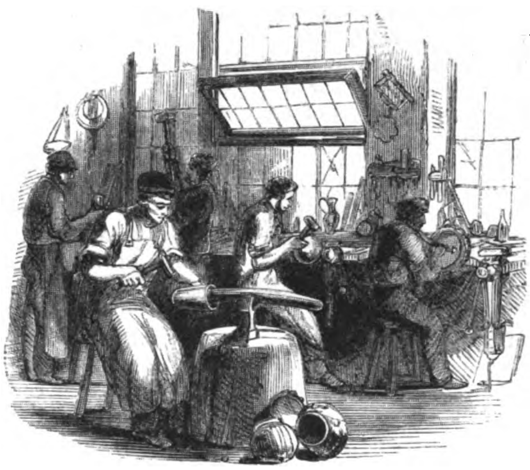


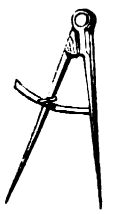
449. SNARLING UP.



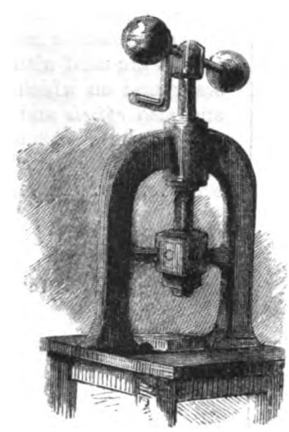
450. CHASING.


451. ANVIL, DIES, SLEDGE HAMMER.


452. HAMMERING.

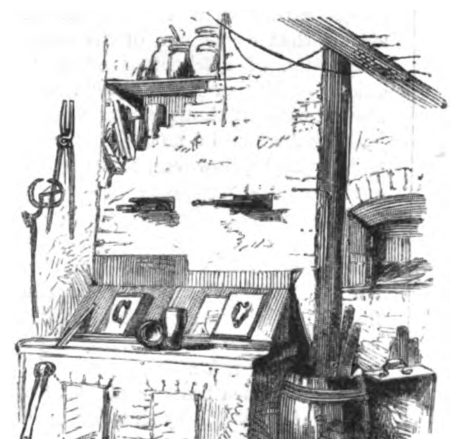

453. CALLIPERS.


454. TRIPLETS.


455. FORK PRESS.


456. FORGE AND IRONS.


457. POLISHING.


458. FURNACES.

XXII.—THE TINMAN.

THE manufacture of tin-plate was described in our *Illustrations of Manufactures* (fig. 512), and it was there explained that the term is a contraction for *tinned-iron plate.* The very thin coating of tin preserves the iron from rust, while the tin itself is the most wholesome and cleanly of metals. It is from this tin-plate that the tinman manufactures the pots, the kettles, the saucepans, the candlesticks, &c. which are so largely used in every household. He receives the tin in sheets, measures it with a rule, marks it with compasses or with a point, and cuts out the various pieces by means of *shears* (fig. 471) or *snips* (fig. 476). He is furnished with *anvils* (fig. 466), for planishing or making quite flat the pieces of plate before they are joined together, which he does by means of the *mallet* (fig. 478). He also has several kinds of anvil known as *stakes* and *teests* (figs. 466, 479), for giving angles or proper curves to the tin plate. He also has a number of irons, such as the *crease iron* (fig. 459), for making small beads and tubes and also for creasing up, and thereby strengthening the edges of articles, a *funnel-stake* (fig. 461) for curving the tinplate, a *horse* (fig. 463) mounted in a wooden block, or let into a square hole in the bench (fig. 470), and adapted to the holding of various swage tools; a *pudding-stake* (fig. 465), also mounted in a wooden block for moulding the surfaces of plates. Then there are *bick* or *beak-irons* (fig. 475), for passing into the interior of vessels, while a part of the exterior is being worked, and also for making long pipes. The tinman also has a variety of *punches* (figs. 462, 462*, 474), for making holes in the plate, for setting the heads of rivets, and some of the punches are made like *swage tools*, *top and bottom tools* or *creases* for making different mouldings and bosses. *Cutting punches* are used with a thin plate of lead or solder laid upon the stake, and on which the sheet to be cut or punched is placed, and also *chisels* and *seamsets* (fig. 464) for cutting notches and closing the seams prepared on one of the stakes. All these operations are sufficiently intelligible without any special description. We therefore pass on to notice the method of joining or *soldering* the various cut pieces of tin-plate, so as to form a finished article.

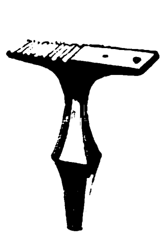
The solder or cement used in joining the different parts of works in tinned iron, is called *soft-solder*, and usually consists of two parts tin and one part lead. It is made into a lump or *pile* fig. 477) and is applied by means of a copper *bit* or *bolt* (fig. 473) misnamed a *soldering-iron*, probably from the circumstance of the copper being riveted into an iron shank; it is fitted with a wooden handle. Before the bit can be used, it must be tinned, for which purpose it is heated in a small charcoal stove (fig. 472) to a dull red, quickly filed clean, then rubbed upon a lump of sal ammoniac, and next upon a metal plate containing a few drops of solder, by which means the tool is coated; it is then wiped with a piece of tow and is ready for use. The edges of the work having been brought together are strewed with powdered resin, and the bit being held in the right hand and the cake of solder in the left, a few drops of the latter are melted along the joint at short intervals. The hot soldering-iron is then made to heat the edges of the metal, and to fuse and distribute the solder along the joint. Two soldering tools are generally in use, the one in the stove, and the other in the hand. The bit must be hot enough to raise the edges to the melting point of the solder, and not too hot to burn off the coating. The bit is intended to act both as a heating tool and as a brush; to pick up small quantities of solder from the pile, and then to distribute them along the edge of the joint. A skilful workman will make a fine and regular line of solder; and he cools the part just finished by blowing upon it. For the best tin wares, muriate of zinc is used instead of resin, and with this the joint is moistened by means of a small wire or stick, before the application of the hot tool.

The tinman often works in sheet zinc as well as tin plate; this is more difficult to solder and does not make so neat a joint, since the zinc is apt to remove the tin coating from the soldering tool. Muriate of zinc or sal ammoniac is used as the flux.

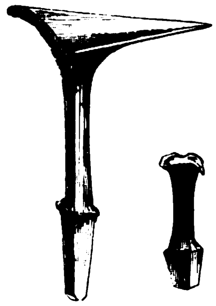
XXIII.—THE SURVEYOR.

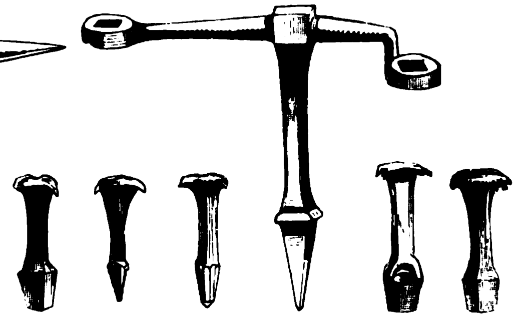
THE surveyor is accustomed to call his employment a *profession* rather than a *trade*, and the distinction is a just one, seeing that every one of his employments requires a special adaptation of intellectual exertion, whereas a trade depends chiefly on skill of hand, which, once acquired, can be exercised almost without thought, and one article is but a copy of the one just finished, and a model for the one that is to succeed it. We think it right, however, to say a few words about the surveyor's employments, preparatory to a notice of the work of the road-maker, the bridge-builder, and the canal and railway engineer; for it is the surveyor who lays out the ground, determines the levels, and marks the most convenient line of route, such as will be the most economical in the making, and the most profitable in the working. The surveyor does all this in addition to his employment of measuring fields, mapping out estates, valuing timber, &c.

The best idea that we can give of the surveyor's work within our brief limits, is by showing how he measures a field. In this country land is measured by means of a chain called, after its inventor, *Gunter's Chain* (fig. 489). It is contrived so as to simplify computation, as far as our clumsy units of area and length will admit. The smallest of the three units of area used for land is the *perch*, and this is the square of one of our units of length, namely the *rod* or *pole;* but the two higher measures, the *rood* and the *acre*, correspond to the squares of no lineal measure. The reader will understand why we speak of squares, from the simple method of ascertaining the area of a given space. We have only to multiply the length by the breadth to get the area in square feet, square yards, &c. Thus, a room measuring 12 feet in its length, and 12 feet in its breadth, has for its area 144 square feet, because $12 \times 12 = 144$, while another room, measuring 6 yards long and 3 yards wide, evidently contains 18 square yards. It happens, however, that the acre is $\frac{1}{10}$th of a square furlong, so that when disposed in a strip 1 furlong in length, it is $\frac{1}{10}$th of a furlong wide, and it was this that determined the most convenient length of the chain, as containing


459. CREASE IRON.

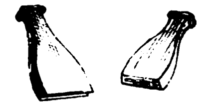

460. BLOCK HAMMER.


461. FUNNEL STAKE.


462. PUNCHES.

463. HORSE.

462*. PUNCHES.


464. CHISELS.

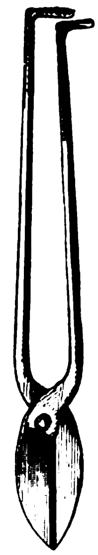

465. PUDDING STAKE.

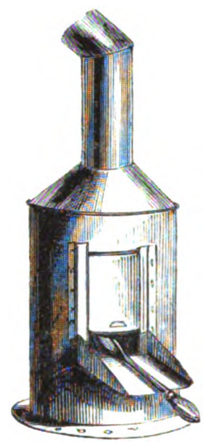

466. POLISHING ANVIL.

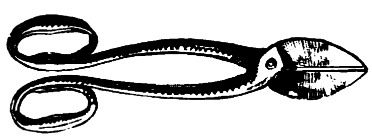

467. BENT SNIPS.


468. TONGS.

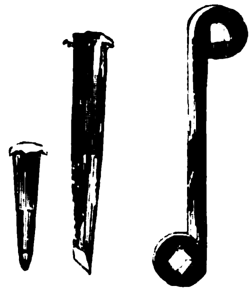

470. WORKSHOP.

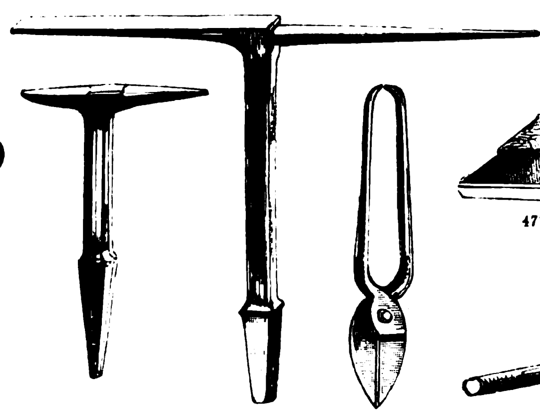

471. LARGE SHEARS.


472. CHARCOAL STOVE.

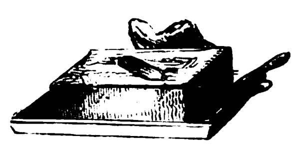

469. SCOTCH SNIPS.

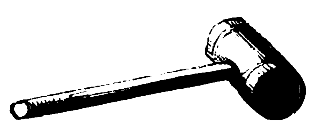

473. SOLDERING IRON.

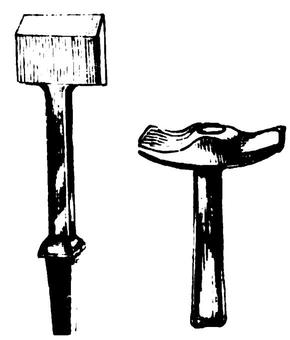

474. PUNCHES AND TWO-HANDED WRENCH.


475. BICK IRONS.

476. STRAIGHT SNIPS.


477 SOLDERING PILE.


478. MALLET.


479. HATCHET STAKE AND HAMMER.

exact though awkward numbers of all the smaller units, namely, 4 *rods* or *poles* = 22 *yards* = 66 *feet* = 792 *inches*. The length of the chain thus becomes the 80th part of a mile, or the 10th of a furlong, and its square the 10th of an acre; $2\frac{1}{2}$ such squares make 1 *rood* or $\frac{1}{4}$th of an acre, and the 40th of this, or the square of a $\frac{1}{4}$ chain, is a *perch*, or square *rod* or *pole*, the smallest unit used for cultivated land. The division of the chain into feet would make the calculation too complicated, by introducing fractions, since the pole is $16\frac{1}{2}$ feet. Some chains, however, when used for measuring distances, only consist of 132 half-foot links; but the usual chain has 100 links, so that the measurements may all be expressed in links, and by simply omitting the last two figures the number of chains' length is at once seen. Thus, 2,135 links = 21 chains 35 links, and as all calculations of area lead to a result in square links, which are $\frac{10}{1000}$ths of a square chain, or $\frac{100}{1000}$ths of an acre, they show at once, by omitting the last 5 figures, the acres, and by multiplying the 5 figures thus cut off by 4, and cutting off the last 5 figures from the product, the odd roods are shown, and by again multiplying the 5 cut off figures by 4, and cutting off the last 4 of the product, we get the odd perches, and the 4 cut off are decimal parts of perches. The link measures 7·92 inches, but neither inches nor feet are used on account of the decimal parts. Between every two links are one, two, or three small rings for the purpose of giving flexibility to the chain. When the chain is required for rough work it is made to consist of 200 half-links, instead of 100 whole ones, to prevent the risk of bending. In order to distinguish the middle of the chain a round piece of brass is introduced, and the 40th link from each end is marked by a 4-fingered bit, the 30th by a triple, the 20th by a double, and the 10th by a single finger; there is also a mark at the 25th link, which renders the counting of odd poles or links a quick operation. The chain has a handle at each end, and the man who pulls the chain is directed by him who follows to place a pin in the straight line with the mark towards which they are proceeding; or in continuing a previous line the leader can himself insert the pin. He has at starting ten of these pins, which the follower picks up as they are left, so that at the end of every furlong they must be given back to him, and an entry of 1,000 be made in the fieldbook.

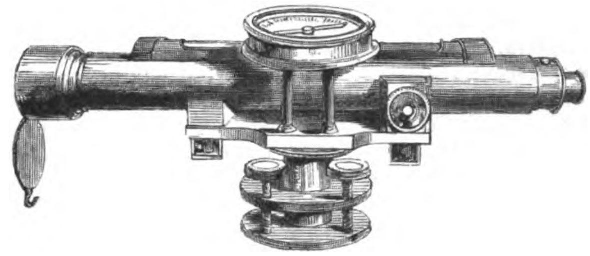
In surveying a single inclosure with 4 straight sides, such as fig. 497, each side is measured, and one diagonal such as A B. On transferring these five dimensions to paper, which is called *plotting*, and dropping a perpendicular to the diagonal A B from each of the other angles, and measuring them by the *plotting-scale*, which will be found in the box of instruments (fig. 500), we multiply half the sum of these perpendiculars by A B, which gives the area of the two triangles of which the common base is A B; or, in other words, we get the area of the whole field. In this way any figure with straight sides, however complex, can be divided into triangles, less in number than the sides by two, and every side of each triangle being measured in the field, their perpendiculars can be measured on paper. For a curved boundary the surveyor measures a straight line as near it as convenient, and makes this line a side of one of the triangles, and while measuring it he takes also a series of distances from different points of it to the curve. These are called *offsets*; they must be perpendicular to the straight line, and are usually measured with rods (fig. 488), placed against the chain without disturbing it. In this way means are furnished for plotting as many points of the curve as there are offsets, and through these points the map may be drawn (fig. 501). The area of each space between two offsets is taken as if the boundary line joining their ends were straight, and this area is found by multiplying the half sum of the two offsets by their interval. The whole offset space must be added or subtracted according as it lies within or without the triangulation of the field. If the surveyor has merely to compute the area, he has no occasion to sketch any map at all, for by proper entries in his fieldbook he has all that is necessary for the computation.

In addition to the chain, the surveyor usually has some instrument for finding the spot in any line from which a perpendicular thereto will reach a given distant point. In this way a good deal of measurement is saved; as for example, in fig. 497, the only use of chaining A B, C B, is to define the place of C, whereas, could we know in the field on what point D of the chained line A B a perpendicular to it from C would fall, we should only have to measure this perpendicular, instead of the two lines A C, C B, both longer than C D. In this way 3 lines instead of 5 would suffice to plot and survey the whole field, and the perpendiculars could be better measured on the field than in a paper plan. The oldest instrument used for this purpose is the *cross staff*, consisting of a piece of board for a head, with two deep saw-cuts in it at right angles. This being mounted on a staff, and planted in some part of A B, and turned round so that through one of its grooves A can be seen in one direction, and B in the other, the observer will see through the other groove to the right or left of C, and he must move the staff along A B until it is placed on a spot which will admit of the three marks A, B, and C being seen through the two grooves. The cross staff has been superseded by the optical square, which consists of two pieces of looking-glass fixed in a box, and inclined 45° to each other. Half the silvering of one glass is removed, and the eye directed to it, can see an object directly in front through the transparent portion, and another object reflected from the other glass to this one, and thence to the eye, so that the latter object must be 90° distant from the former, and by walking along the part of A B where we expect the perpendicular to fall, with the instrument at our eye, and A in sight through it, various objects about C will appear reflected in succession, and when the image of C itself coincides with A, we are at the right spot.

The instrument commonly used for measuring horizontal angles is the *theodolite* (fig. 491). In its simplest form it consists of a divided circle, which is to be set parallel with the horizon, and a telescope which moves in a vertical plane, so as to allow the observer to view any object which he may require above or below the horizon.

In laying out a line of road, railroad, or canal, the operation of *levelling* is required. Its object, as its name implies, is to ascertain the relative heights of points on the ground along the line of operation, for which purpose convenient stations are selected, and the distances between them ascertained. A kind of telescope called a *level* (fig. 481), is set up at or near the middle of the interval between two stations (fig. 480): it is made horizontal by means of adjusting screws, and an assistant at each station holding a station staff upright, as at fig. 482, moves a vane or index along it according to the directions of the surveyor at the telescope, until the index appears to coincide with the crossing of two wires fixed in the telescope. Having observed one staff in this way, the instrument is turned round without disturbing the stand, and the surveyor makes a similar observation and adjustment for the other staff. In this way proceeding along the line, and entering in a fieldbook the height of each staff from the ground up to the adjusted index in every case; entering one set of observations as *fore-sights*, and another set as *back-sights*, the difference between the sums of the numbers in the two columns will be equal to the height of one extremity of the line above the other.

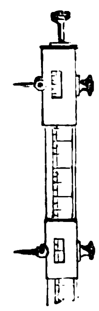
480. SURVEYOR.



481. LEVEL.

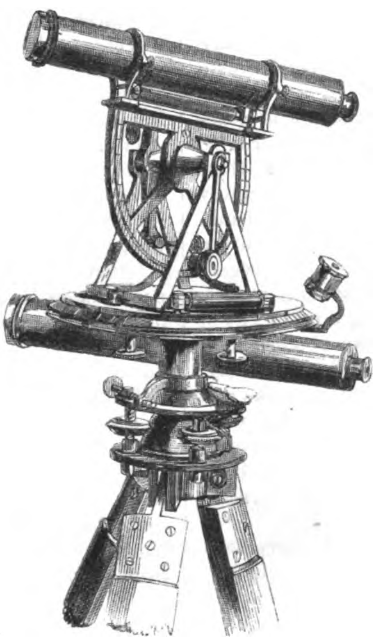
482. ASSISTANT SURVEYOR.

483. BOW PENCIL.

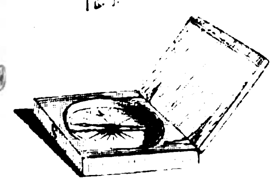


484. BEAM COMPASSES.

485. TAPE MEASURE.



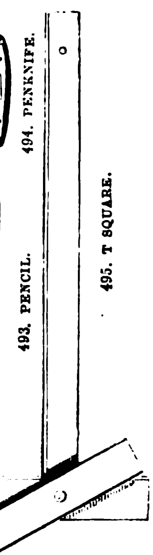
491. THEODOLITE.



486. COMPASS.

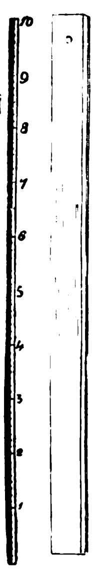
494. PENKNIFE.

493. PENCIL.

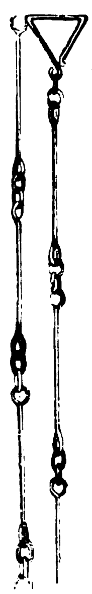


495. T SQUARE.

487. STAFF AND FLAG.

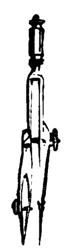


488. ROD AND STRAIGHT EDGE.

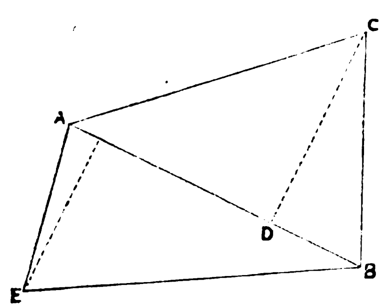


489. GUNTER'S CHAIN.

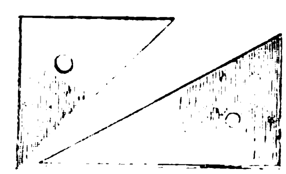
490. MATHEMATICAL PEN.



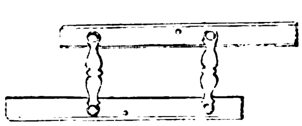
492. SPRING BOW PEN.



497. FOUR-SIDED FIELD.

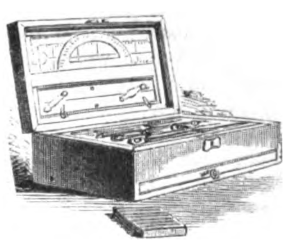


498. SET SQUARES.

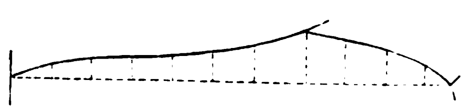


496. PARALLEL RULE.

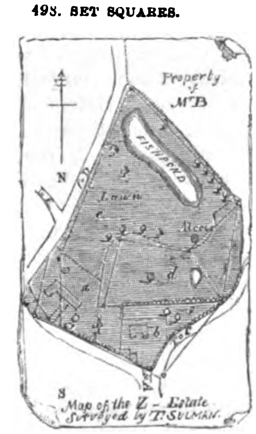
499. COMPASSES.



500. BOX OF INSTRUMENTS.



501. OFFSETS.



502. PLAN OF AN ESTATE.

XXIV.—THE ROAD-MAKER.

Few occupations are of more importance to a community than that of the road-maker. It has been well remarked that roads, canals, and navigable rivers may be considered as the veins and arteries through which all improvements flow. To internal trade and agriculture, they are as the veins and arteries of the human body through which the blood flows in every direction, and gives life, health, and vigour to the whole frame; but if the circulation be stopped in any one part, that part must suffer and re-act injuriously on the rest. So it is in a civilized country: without roads its otherwise most valuable productions have scarcely any value: its finest timber is often a source of inconvenience instead of wealth; its coals and metallic ores must lie undisturbed; agricultural produce benefits only the immediate producers of it; the sheep is killed for the sake of the fleece only; and above all, man is separated from man, family from family, and the soothing and civilizing influences of intercourse with his fellows are greatly abridged.

The ancient Romans were our masters in the art of road-making. In every part of their vast empire they constructed roads, many of which still remain. They connected their different military stations by means of straight lines, skilfully overcoming natural obstacles by means of cuttings, embankments, bridges, and tunnels. Their first care was to secure a good foundation for their road, for which purpose they began, where necessary, by ramming the ground with smooth stones, fragments of brick, &c., and on this constructing a pavement of large stones firmly set in cement. Squared stones were occasionally used, and when irregular they were made to fit accurately. Basalt and the tough metal furnished by the primitive rocks was preferred, and if large stones could not be had, small ones were cemented together with lime, so as to form a kind of concrete to the depth of several feet. The road was generally raised above the level of the ground, and there were usually two carriage tracks with a raised footpath in the centre.

With such an enduring model before them it might have been supposed that no doubt could have arisen as to the true principle of road-making; nevertheless, for many years the roads of Great Britain were constructed on two opposite principles; the first, that of Telford, who, following the Roman model, required the road to be laid down on a hard, solid, carefully prepared foundation, and the second that of M'Adam, who was indifferent whether the substratum were soft or hard, but of the two rather preferred the former. It is scarcely necessary to remark that Telford's method at length prevailed, and some of the finest roads of Great Britain were constructed under his immediate direction.

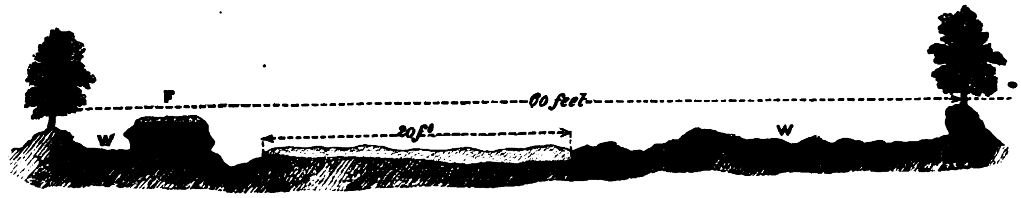
In laying out and surveying a line of road, a straight line is preserved, except when it is required to gain the proper rate of inclination without expensive cuttings or embankments. A convenient inclination, or *gradient* as it is called, is 1 in 35, and where the traffic is considerable, the width should not be less than 30 feet, exclusive of a footpath of 6 feet. The road should not be too convex, but the cross section should be formed of two straight lines inclined at the rate of 1 in 30, and united in the centre or crown of the road by a segment of a circle having a radius of about 90 feet.

In the great Holyhead road, Telford's foundation consisted of a rough, close-set pavement made of any common stone which the neighbourhood afforded. Where necessary, these bottom stones were laid with their broadest faces downwards, and the interstices were filled with stone chips, well driven in, to prevent the earth beneath from being pressed up and mixing with the coating of broken stones, and thus forming mud. When the coating is laid upon this well-prepared foundation, the stones soon wedge together into a solid uniform mass, vastly harder than a great thickness of broken stones mixed with the earth of the sub-stratum. It is of great importance to produce this hardness and smoothness of the surface, as will be seen from the results of an experiment made on different kinds of roads:—a wagon was drawn on a well-made pavement with a force of 33 lbs.; on one of Telford's roads the power required was 46 lbs., on a road made with a thick coating of broken stone laid on earth 65 lbs., and on a gravel road also on earth 147 lbs.

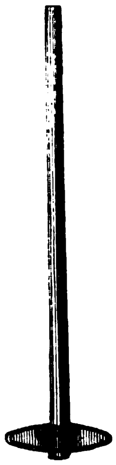
Figs. 503, 504, will serve to illustrate Telford's method of improving an old road. In the former figure, W W represent waste ground; in both figures F represents the footpath, and in the latter figure, *s s* the green sod, and *d* a pipe-drain. In fig. 506, the paved foundation with a layer of broken stones above it is represented at B S, the natural surface being shown at N S. *g* is the gravel footpath, *s* green sod, *d d* pipe-drains, D D main drains, P P posts. The transverse section of the road being gently convex will assist the drainage, and the ditch on each side should be sufficient to receive and carry off all the water that may fall on the road. The pipe-drains should be at distances of about 60 feet, and in cases where the substratum is a strong clay or a wet peat, trenches or drains must be formed across the road every 20 or 30 feet, each trench being about 4 inches square internally, formed of bricks or flat stones, as in fig. 509, the remainder of the trench being filled up with coarse stones. In districts where stone is scarce, but where lime and gravel are abundant, the foundation of the road may be formed of concrete.

M'Adam's method of forming a road of angular pieces of stone, without any kind of cement or binding material, is still adopted, whether on a hard foundation or not, and his name has been perpetuated in the verb to *macadamise*, which is applied to the process introduced by him. Tough hard stones should be used, and be broken to such a size as to pass freely through a ring 2½ inches in diameter.

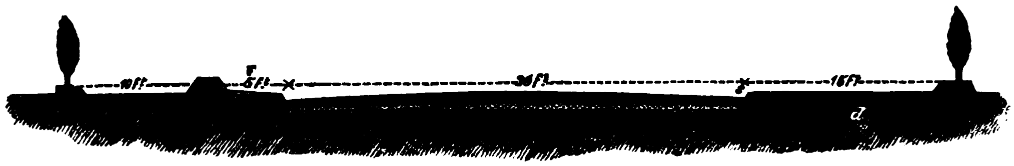
The tools used in road-making are few and simple. In working in clay, as in digging drains, &c., a narrow spade, considerably curved in the blade, called a *grafting tool*, is used. The best kind of *shovel* for road-work is represented in fig. 507; it is pointed in the blade, and has a curved handle to allow the labourer to bring the blade flat to the ground without stooping. Where metal rails can be laid down, a small *truck* or *wagon* holding about a cubic yard of earth can be used. Two kinds of *hammers*, one of which is represented in fig. 505, are used. The handle should be flexible and of straight grained ash, especially when used for breaking pebbles. The small hammer should have a chisel face, and the large one a convex face about five-eighths of an inch in diameter. They should be of cast steel rather than wrought iron. The *pronged shovel* (fig. 512) is useful for filling broken stones into carts or barrows, the advantage of this form being that the earth is not taken up with them. *Scrapers* are sometimes made of wood shod with iron, but those of plate iron are the best; the blade should be 6 inches deep and from 14 to 18 inches long, and turned round a little at the ends to prevent the mud, &c. from escaping. The *patent road-scraper* consists of a number of scrapers placed in a frame and mounted on wheels. It is worked across the road, and deposits the mud or dust at the side. Scraping keeps the road firm and hard, for the dirt retains water on the surface like a sponge: it also allows the surveyor to take advantage of the proper weather for repairing the roads, and it greatly assists fast travelling. A *sweeping machine* consists of a kind of endless broom, passing over rollers attached to a mud-cart, and so connected by cog-wheels with the wheels of the cart that when the cart is drawn forward the broom revolves and sweeps the mud from the surface of the road, up an inclined plane into the cart. A *hedging knife* or *plashing tool*, attached to a long handle, is also used for trimming hedges. *Working levels* are used in laying out new works and repairing old roads. Fig. 511 is a useful form of level. On the horizontal bar, M P, are four gauges, *a*, *b*, *c*, *d*, moving in dovetail grooves, so that when adjusted to a proper depth below the horizontal line, they can be fixed by thumb-screws. In this way the proper transverse section of the road is formed. A plummet in the centre of the level shows when the straight edge is horizontal, and a line drawn near the end of the bar at M marks the middle of the road; 4 feet from this the gauge *a* is fixed to the depth required by the curvature of the road, and the



503. CROSS SECTION OF AN UNIMPROVED OLD ROAD.

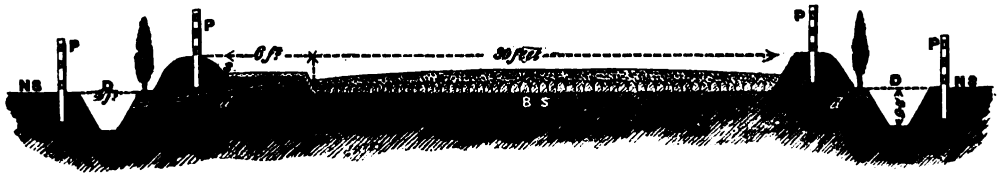


505. STONE-BREAKER'S HAMMER.



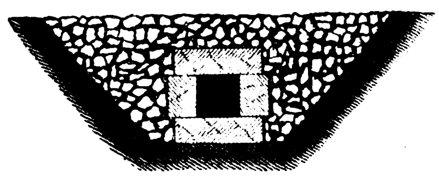
504. CROSS SECTION OF THE SAME ROAD WHEN IMPROVED.

507. SHOVEL FOR ROAD-WORK.



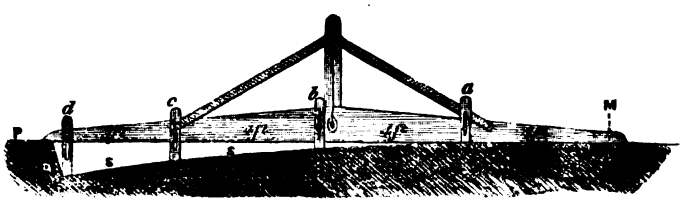
506. CROSS SECTION OF A NEW ROAD WITH A PAVED FOUNDATION.

508. ROAD-PITCHING (*up hill*).

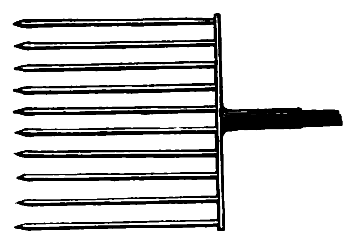


509. ROAD DRAIN.

510. ROAD-PITCHING.



511. WORKING LEVEL.



512. PRONGED SHOVEL.

513. STEPPING-STONES.

514. PRIMITIVE BRIDGE.

other gauges are in like manner arranged so that their lower ends shall coincide with the surface of a road 30 feet wide. Levels are also used for laying out slopes: such as a bar of wood 3 inches deep, 1 inch thick, and 6 feet long: near the middle of the rod is fastened a triangular piece of wood so formed that when the rod is placed on a slope of from 1 to 2 or from 1 to 3, a pocket spirit level placed on one of the sides of the triangle shall be horizontal and the bubble remain in the centre.

Where the traffic is considerable, as in roads near or through towns, a good foundation is of the utmost importance. Indeed, it is customary to regard the foundation in any case as the real road, and the top covering or pavement as a contrivance for preserving it. The foundation may be of concrete or of broken stones, or the old road itself may be the foundation, but the stones must be taken up and relaid to the proper cross section, and upon this the stone pavement should be formed, the stones being bedded in some coarse kind of mortar. Granite is the best stone for paving, that of Guernsey or Aberdeen being preferred, as it does not become polished on the surface by wear. The stones should be in rectangular blocks from 8 to 15 inches in depth, about 18 inches in length, and 3 or 4 inches wide. Narrow stones wear better than wide ones. They must all be of the same depth, otherwise hollows will be formed on the surface. The courses should break joints, as in masonry or brickwork (figs. 163—168, 198—205), and there should be a firm kerb on each side of the road for the courses to abut against. The courses should be begun on each side and worked to the centre, and the last stone should form a key to the whole. The stones should then be rammed down with a heavy *punner*. After the pavement has been laid, it is usual to pour over it a thin grouting of sand and lime, but this is very inferior to bedding the stones in mortar. Where the inclination is considerable the pavement is laid, as in fig. 508, with a course of slate between the rows of stones, in order to give horses a hold for their feet, a result more usually obtained by placing the stones in a sloping position, as in fig. 510.

The enormous traffic of London tries the ingenuity of our road-makers, as well as the pockets of the rate-payers. When it is considered that London pavement costs about 20*s.* per square yard, and that in a crowded thoroughfare it requires frequent repair, and every few years relaying, we cannot wonder that persons are seeking new solutions to the problem how to construct a cheap, durable, and not very noisy road. Wooden blocks, asphaltum, and other materials have been tried, but hitherto no *road-metal*, as it is called, has been found to resist the wear and tear of a London thoroughfare so well as a granite pitching on a good foundation.

XXV.—THE BRIDGE-BUILDER.

Bridge-building is a branch of road-making, a bridge being a constructed platform supported at intervals for the purpose of carrying a roadway over a strait, an arm of the sea, a river, a canal, a valley, or over another road. It differs from a *causeway* or *embankment* where the roadway is continuously supported. *Aqueducts* for conveying streams of water or canals, and *viaducts* for carrying roads or railways, are practically bridges. The bridge must form not only a permanent roadway above, but allow easy passage for shipping in the stream below. In some cases, however, where the stream is wide and rapid, and liable to be beset with ice in winter, and from other causes a stone bridge is not practicable, a *bridge of boats* is used, as in fig. 518, in which a number of boats are moored in the stream, and a roadway is laid down upon them: in order to allow the passage of large craft, the traffic is occasionally interrupted, and a certain number of the boats or pontoons are swung aside to allow the vessels to pass.

The art of bridge-building varies greatly with the social and intellectual condition of the people among whom it is practised. The *stepping-stones* (fig. 513) across the brook are one of the most primitive forms of bridge; scarcely less so, is the *plank* resting on the two opposite banks. In the mountainous districts of South America, ropes made of rushes or leather are stretched across the stream, and connected and covered in some way so as to form a slight bridge. An elaborate kind of *rope bridge* is shown in fig. 515. Fig. 516 represents a *cane suspension bridge*, and fig. 517 a rude but efficient *timber bridge*.

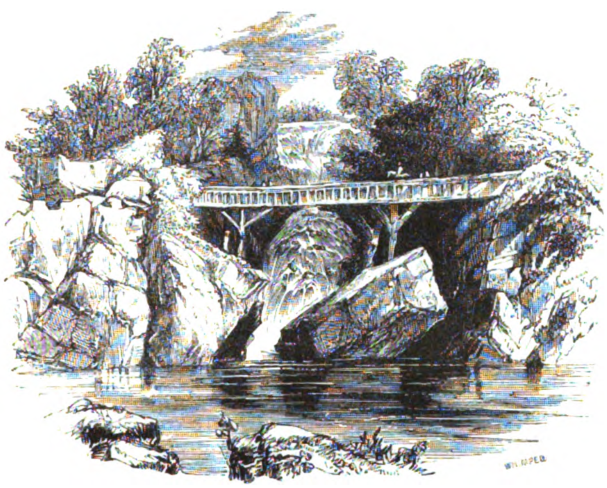
The most permanent form of bridge is that of *stone*, with circular or elliptical arches. The Romans were great masters in the art of bridge-building, and some of their structures remain to the present day. The working and setting of the parts of a stone bridge belong to the mason, as the art of combining the timbers of bridges belongs to the carpenter. Bridges of brickwork are built by the bricklayer, and those of iron by the smith and engineer; but whatever the material, there is always an architect or engineer to preside over the work.

Of all these materials stone is the most durable, and is to be preferred. We shall therefore confine our few elementary details to the construction of this kind of bridge. In no building are the *foundations*, consisting of the underground work of the *piers* and *abutments*, of more importance, and various methods have been adopted for constructing them. In shallow rivers, stones were sunk to the bottom in strong baskets, and additional stones were piled up within them, until within a foot or so of the lowest water surface. Strong wooden chests or *caissons* were also filled with masonry aboveground, and sunk into the bed of the river, a plan adopted in forming the piers of the old Westminster and the present Blackfriars bridges. In rapid streams, the ancient plan was to build the piers on dry ground by the side of the river, but ranging with its general direction, and at right angles with some direct approach previously agreed upon, and when the bridge was completed, to turn the course of the river by a new channel through the water-way of the bridge Even where the course of the river was straight, or nearly so, it was so difficult and expensive to construct the piers in the water that the engineer did not hesitate in some cases to build a bridge on dry land, and then turn the river under it. If the bottom proved unsound, piles were driven over the site of the proposed piers, and the tops of the piers were covered with a coarse concrete of lime and gravel, and on this the firs course of stone was laid.

In modern times, the *coffer-dam* allows the engineer to secure a firm foundation in the bed of the river. Suppose, for example, the pier of a bridge is to be erected in a tidal river, where there is a depth of 10 feet of water at the lowest spring tides, and that the bottom consists of 12 feet of loose gravel and sand resting on clay. If the depth at high-water be 28 feet, we thus get a depth down to the clay of not less than 40 feet. In such case the coffer-dam must be formed of four rows of piles, as shown in the transverse section (fig. 521), and the spaces between them must be filled with clay-puddle, thus forming three distinct *puddle walls*. The whole having been made water-tight, the water can be pumped out from the inclosed space, and the ground excavated for a foundation as on dry land. The piers should intercept the water-way of the river as little as possible, but their thickness must be regulated by their height as well as by the span and rise of the arches. Under low-water the piers should increase in breadth to the foundation, and the exposed ends should be provided with sharp angles to act as *cut-waters*. In building the pier, provision should be made for the

515 ROPE BRIDGE.

516. CANE BRIDGE, CEYLON.



517. BRIDGE AT NORWICH, CONNECTICUT.

518. BRIDGE OF BOATS.

519. PONT Y PRIDD, WALES.

520. SUSPENSION BRIDGE, PESTH.

abutments of the arches, and also for supporting the *centre*: this is a timber framing required for supporting the separate stones or *voussoirs* of the arch, until they are keyed in. The centre must be strong enough to bear the weight of the voussoirs without any sensible change in form, and admit of being easily removed when the arch is finished. A good deal of skilful carpentry has been expended on the construction of centres, and eminent bridge-builders, in the detailed accounts of their several structures, usually describe with great minuteness the construction of the centre. The form and dimensions of the arch-stones or voussoirs vary greatly, from a depth of 6 feet to $2\frac{1}{2}$ feet or less. Each course should be of equal thickness quite through, and the beds should be worked as true as possible for the whole breadth of each stone. The key-stones should be driven in so as to fill their places firmly, and when finished, the work should be left for some time to dry and get hard. In the meantime the outside work is being proceeded with, and when the centre is at length removed, the interior surface of the arch, called its *intrados* or *soffit*, is carefully examined. The key-stone occupies the highest point or *crown* of the arch: those parts of the pier from which the arch springs are called the *abutments*, and the points where the intrados meets the abutments, the *springings* of the arch, and just above this are the *flanks* or *haunches* of the arch. The horizontal space between the springings is the *span* of the arch, and the distance from the centre of this line to the key-stone is the *rise* or *height* of the arch. The exterior surface is called the *extrados* or *back* of the arch.

The *spandrels* of a bridge are the spaces between the haunches of an arch and its highest point at the extrados of the roadway. These spaces may be filled up with earth or gravel, or they may be formed into vaults. The points of the piers are brought up and finished at some distance above high-water mark by sloping them back to the face of the spandrel in a triangular or circular form, or disposing them to receive columns, pilasters, or turrets. When the spandrels have been brought up to the level of the top of the arch-stones, they are dressed into the slope which it is proposed to make the roadway. A cornice is usually laid down, extending along the whole of the arches, spandrels, and wing walls. There is also a *parapet* consisting of a *plinth*, *dado*, and *coping*. The parapet may be from $3\frac{1}{2}$ to 6 feet above the footpath or roadway. The dado or middle member is about 10 or 12 inches thick; the plinth has an offset of about an inch on each side, and the coping is usually made to slope each way from the middle. Balustrades are sometimes introduced instead of the dado. When the spandrels have been covered, the foundations for the footpaths are built with rubble-stone for the outside kerbing. The footpaths may vary from 3 to 6 feet in breadth. If the carriage way is to be paved, there should be laid on the covering of the spandrels and over the top of the arches, a thick bed of gravel mixed with loam, in which squared paving-stones are to be set and well beaten, so as to make a curve across the road of 6 inches in 24 in breadth. But if the roadway be of gravel it must be laid 22 inches in depth in the middle, and 18 inches near the sides. A gutter of small squared stones should be formed on each side of the roadway to carry off the water.

Some splendid stone bridges have been built in modern times. The fine bridge of sandstone over the Dee at Chester, has for its centre circular arch a span of 200 feet, while London Bridge, built of granite, has a span of 152 feet, the form being elliptical. The extensive introduction of railways has given our engineers abundant opportunity of showing their skill in bridge-building; thus the railway bridge at Maidenhead, built of bricks, laid in cement, presents elliptical arches of 128 feet in span; they are among the flattest arches known. This latter bridge is the boldest that was ever constructed, considering the material and the form of the arch, the very heavy traffic to which it is exposed, and the tremor and vibration consequent thereon.

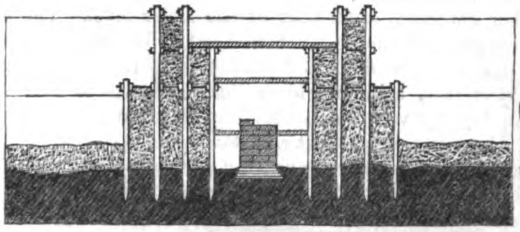
In countries where timber is plentiful, timber bridges have obtained considerable celebrity, on account of the scientific carpentry concerned in their production. We may also refer to *suspension bridges*, which in many cases may be quite independent of the bed of the river which they cross. A suspension bridge may be often erected where from the rapidity of the current, or the height of the banks, a stone bridge would not be practicable. A bridge of this kind, however, is much slighter than one of stone, so that where the traffic is heavy and considerable the latter must be preferred; but for large openings, where the traffic is small, the suspension principle is good; for the bridge can be carried to almost any span and any height at a comparatively small cost. The *rope bridge* (fig. 515) and the *cane bridge* (fig. 516) are quite as much suspension bridges as the more important structure, fig. 520. A suspension bridge, as usually constructed, consists of a chain or set of chains, secured by their extremities to solid rock or masonry on each side of the stream, and then passing over the tops of piers arranged for the purpose, falling down by their own weight into a catenary curve over the stream. From this chain the roadway is hung by means of vertical rods, so that from the method of suspension, the road is subject to constant vibration, not only from the traffic, but also from the action of wind. The links of the chain are of very large size, as may be seen from the specimen, fig. 522.

Of late years *iron*, *girder*, and *tubular* bridges have come into use in consequence of the increased facility with which iron is now manufactured. An iron bridge usually consists of ribs of cast iron, supporting perpendicular spandrel pieces of the same material upon which the roadway is carried. In girder bridges wrought iron is substituted for cast, for which purpose plates of rolled iron were originally joined with rivets with a strap of angle-iron attached on each side, top and bottom, so as to form artificial flanges. Greater strength was obtained by adopting the tubular form, using T-iron for the vertical ribs and arranging the side plates vertically. The finest example of the tubular bridge is that over the Menai Straits, fig. 538, while the section, fig. 539, will give some idea of the structure of the tube.

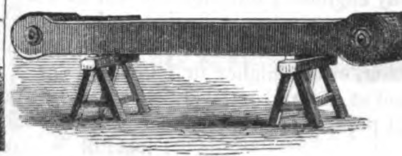
XXVI.—THE CANAL ENGINEER.

It was not until the year 1758 that those useful auxiliaries to roads, *navigable canals*, were introduced into this country. At this period the force of traction on our best roads was not less than $\frac{1}{8}$th or $\frac{1}{10}$th of the load or carriage, and when this was heavy, the speed did not exceed two miles, or two and a half miles per hour; whereas, on a canal, the force of traction at that pace is not above $\frac{1}{1000}$th, or at most $\frac{1}{500}$th, of the load. The Duke of Bridgwater, with the assistance of his engineer, the celebrated Brindley, could not help making these advantages manifest, so that between the dates of the completion of the Bridgwater canal and the opening of the first railroad in 1830, not less than 2,200 miles length of navigable canals had been constructed in England alone; while, in addition to canals, such rivers as were capable of it were rendered navigable. The introduction of railroads has not only not superseded canals, but in some cases has actually improved their traffic, since the tendency of a railway is to increase traffic, and the comparatively low rate of water-carriage insures to the canal its share of business.

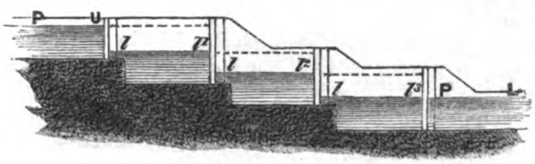
In the construction of a canal, the engineer has to consider how he can best construct his watery road on a perfect level, or series of levels. This is done by one of three methods, such as



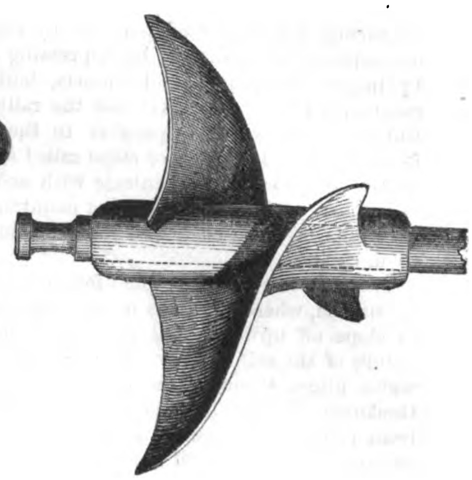
521. COFFER DAM.



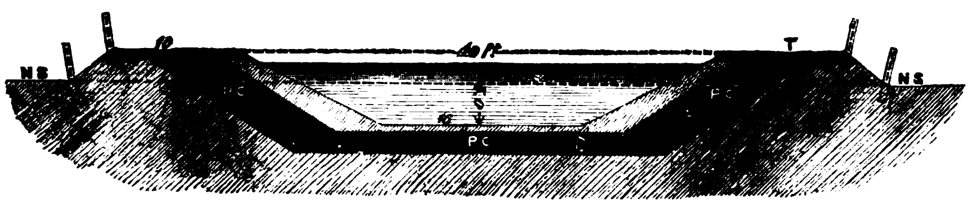
522. LINK OF SUSPENSION CHAIN.



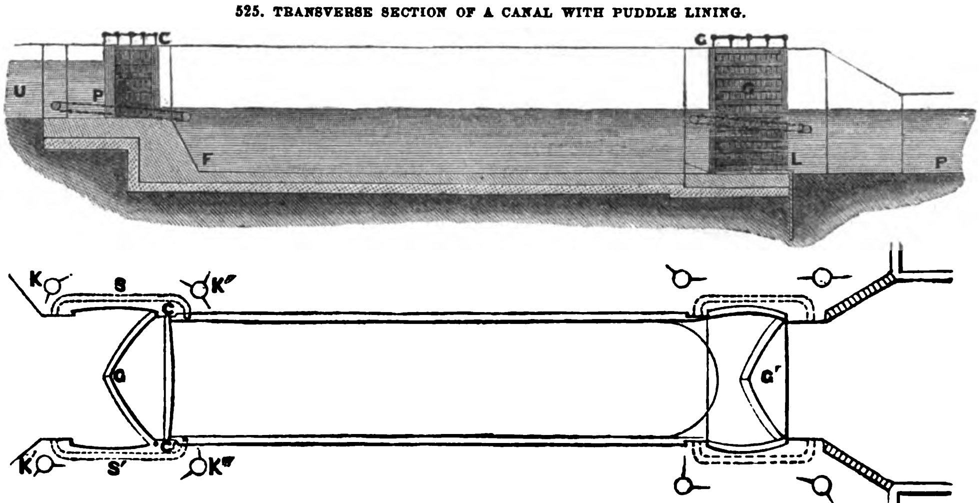
523. SERIES OF LOCKS.



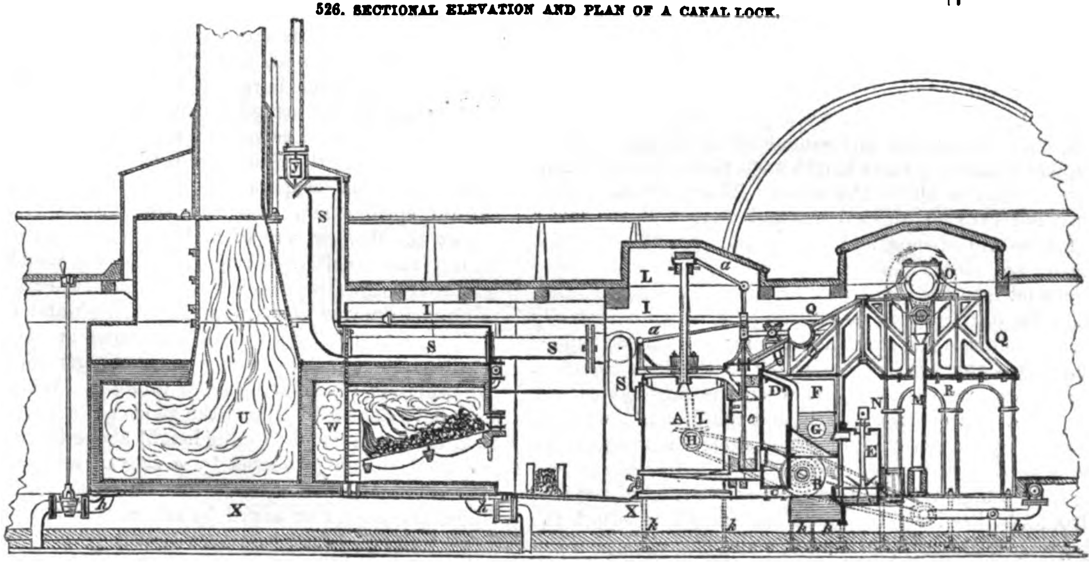
524. SCREW.



525. TRANSVERSE SECTION OF A CANAL WITH PUDDLE LINING.



526. SECTIONAL ELEVATION AND PLAN OF A CANAL LOCK.



527. SECTION OF A MARINE ENGINE.

by raising the depressed portions by means of embankments and aqueducts; secondly, by depressing the elevated portions by means of cuttings and tunnels, both which methods are common to the road-maker and the railway engineer; but the third method, which is peculiar to the canal engineer, is by forming a series of stairs or steps called *locks*, by which one level portion is made to communicate with another, either higher or lower than itself, the water being maintained at the higher level by means of gates so placed that the fluid pressure shall keep them closed.

The form of channel adopted for the canal is such that, except in tunnels, where the sides may be vertical, the bottom is made to slope off upwards, the amount of slope depending on the nature of the soil. Where the soil or rock is so porous that the water filters through, the excavation is usually lined with a thickness of from $1\frac{1}{2}$ to 3 feet of puddled clay, or clay well beaten up or tempered with mortar, and then mixed in a certain proportion with gravel, sand, or chalk; for if clay were used alone, and the water sank below the usual level, the clay would crack, and when the water rose again, would escape by the cracks. It is also usual to form a trench three or four feet in width, in the middle of each side bank, to at least three feet below the bottom of the canal, and this *puddle-ditch*, or gutter, is filled up with puddling stuff, its chief object being to prevent rats and vermin from perforating the banks. In fig. 525, *PC* represents the puddle-lining, 1 foot 6 inches thick at the bottom, and 3 feet in the slope; *T* is the towing path, 10 feet wide; *NS* the natural surface.

It has been stated that the ascent to a higher level or the descent to a lower one is made by means of locks. The level portions between the locks are termed *pounds*, and the frequency with which locks and pounds alternate will of course depend upon the undulations of the ground. If this rise uninterruptedly, or rise and fall at short intervals, the pounds will be short and the locks frequent; while, if the ground be tolerably level, few locks will be wanted. A single lock usually consists of an oblong chamber about 70 or 80 feet long, *CC′* (fig. 526), and 7 or 8 feet wide. Its sides and *invert*, or floor, are lined with brick or stone. It is by means of this chamber that an upper pound is connected with the pound next below it, or a lower pound with the next upper one. Thus *UP* is a portion of the upper pound, and *LP* of the lower pound, which is on the same level as the floor of the lock chamber. *PG* are the gates which retain the water at the upper level: they are curved, as shown in the lower figure, and when in motion, turn upon their ends *CC′*, as centres. They are wide enough to meet and form an angle at *G*, so as mutually to support each other, and the pressure of the water against them keeps them more closely shut. They are opened by means of *capstans*, *KK′*, working chains attached to the gates under the water, and passing through tunnels in the sides of the lock. They are closed by two other capstans, *K″K‴*, the gate, *CG*, being shut by *K‴*, and the gate, *GC′*, by *K″*. A similar pair of gates is placed at the lower end of the lock, *CL;* they are on the same level as the upper gates, and consequently have a greater length than those, in proportion as the lower pound is above the upper. When a barge has to pass from a lower to an upper level, and arrives at the lower gates, *LG′*, these are opened, and on the boat passing into the lock-chamber, are closed behind it. Water from the upper pound is now let into the lock-chamber by opening the channels *SS′*, in the sides of the upper part of the lock, which are usually kept closed by sluices. Water then pours in from the upper pound, and raises the level of the water in the lock chamber. The boat of course rises with it, and when the flow has ceased, the upper gates, *G*, are thrown open, and the boat is towed out of the lock, and proceeds on its journey along the upper level. The whole of this operation is called *locking-up*. In *locking-down*, or passing from a higher to a lower level, water is admitted into the lock from a higher level, the gates are opened to admit the boat, and are then closed upon it, while the sluice is opened in the opposite gates for letting out the water until its surface in the lock chamber coincides with that of the lower level. The gates are then opened, and the boat is towed out as before. Thus it will be seen that a series of locks form a kind of liquid staircase by which the boat may ascend or descend without ever ceasing to float, but by varying the level of the water in the inclosed space. In this arrangement a certain quantity of water is lost from the higher level, but by making the locks double, so as to allow the boats to pass alternately up and down, only one lockfull is required between each pair, since every ascending boat requires a lockfull of water, and leaves the lock full, and every descending boat finding the lock full, does not draw upon the upper pound for water.

Where the slope is considerable, a chain of locks is formed (fig. 523), so that the lower gates of one chamber may form the upper gates of the next below it. In this way only one more than half the number of gates for the whole of the chambers (supposing them to be detached) is required, and much of the machinery for opening and shutting them is saved. In this arrangement there is a great waste of water in certain cases, as for example:—

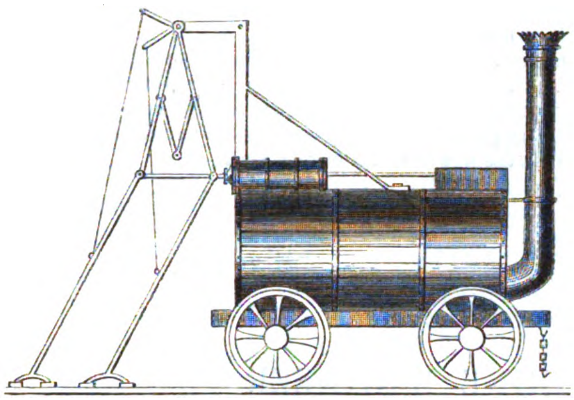
	Finds the locks,	*Lets out of the upper chamber,*	*Leaves all the locks,*
Boat descending.	Full.	None.	Empty.
	Empty.	One lockfull.	Empty.
Boat ascending.	Full.	One lockfull.	Full.
	Empty.	As many locksfull as there are contiguous chambers.	Full.

When the chambers are said to be empty, it is not meant that they contain no water, but that the water is in each at its lower level ll^1 ll^2 &c. (fig. 523), the dotted lines showing the levels in the full locks. Hence, when a number of boats follow each other in the same direction, up or down, each boat will require one lockfull of water; but if a number of boats pass alternately up and down, each pair will require between them as many locksfull as there are contiguous lock-chambers, which in the case of fig. 523 is three, for the previous boat having left all the chambers empty, the ascending boat will require three locksfull, but as it leaves all the chambers full, the next descending boat will not draw off any water from the upper chamber.

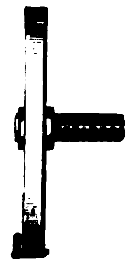
By means of the *double lock*, one half of the water which would otherwise escape to the lower level is saved. The double lock consists of two oblong chambers placed side by side, separated by a brick partition in which is a sluice connecting the two chambers. Now supposing one of these chambers filled to the level of the upper pound, and the other chamber to that of the lower pound, a boat about to ascend would be towed into the chamber where the level was lower, and all the gates being closed, the water from the full chamber would be let into the other, until there was an equality of level in both. The sluice would then be closed, and water admitted from the higher pound, by which the barge would be raised to the higher level, and the upper gate being opened the barge would be towed out.

It is important to economize the water of the canal as much as possible, since the canals are constantly losing water from the locks and from evaporation, and the supply is by means of natural springs and rain. In some cases it is necessary to collect the flood-waters of higher grounds into reservoirs for feeding the canal when required. In dry weather it has even been found necessary, in order to maintain the traffic of the canal, to purchase water from the neighbouring water companies.

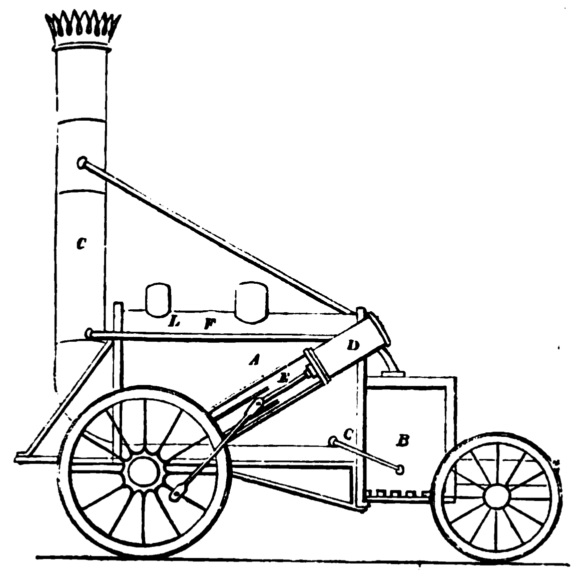
The boats or barges used on canals are much longer and narrower than those used for river navigation, the form being favourable to speed and ease of draught. What are called *fly-boats* have flat bottoms, and the goods are stowed in them nearly from end to end, and to some height above the edge of the boat, the whole being protected by a canvas covering. There is a mall cabin at the stern end for the boatmen. The boats and barges are *tracked* or towed by one or two horses, at the rate of 3 or 4 miles an hour: there is a towing path at the side, and the



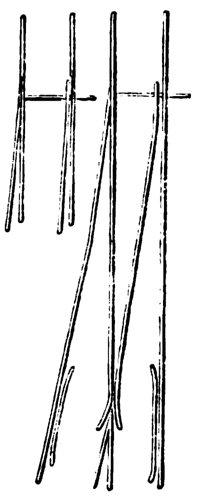
528. BRUNTON'S "MECHANICAL TRAVELLER."



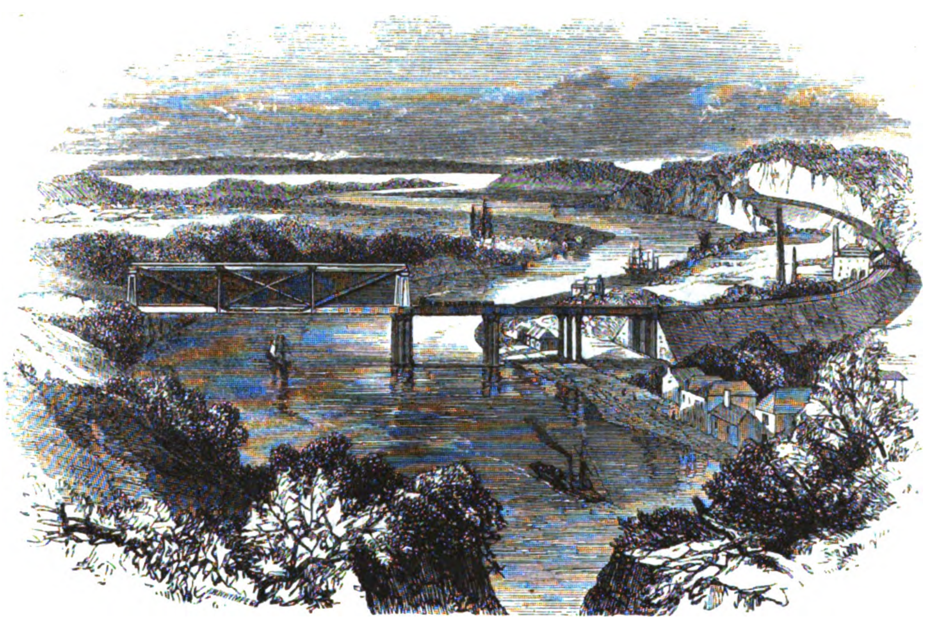
529. WHEEL ON TRAM-PLATE.



530. THE "ROCKET.'

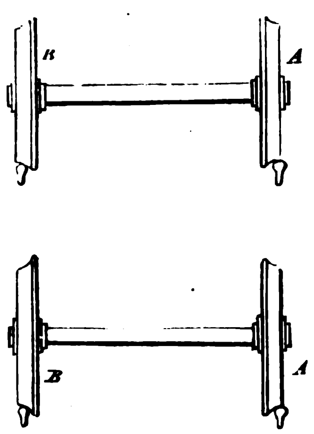


SWITCHES AND POINT

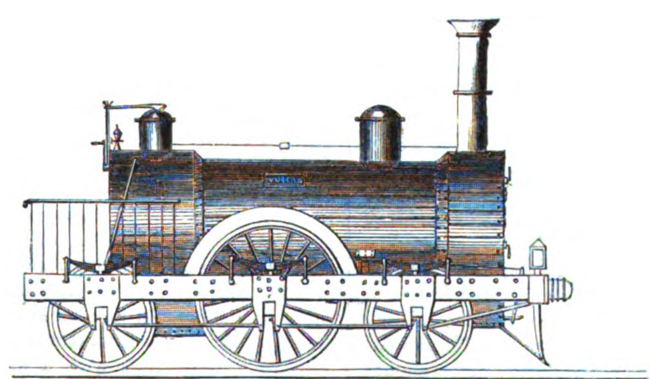


532. BRIDGE OVER THE WYE.

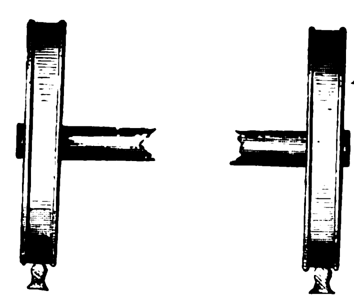
533. TOWER FOR TUBULAR BRIDGE.



534. CONICAL STRUCTURE OF WHEELS.



535. MODERN LOCOMOTIVE ENGINE.



536. EDGE-RAILS.

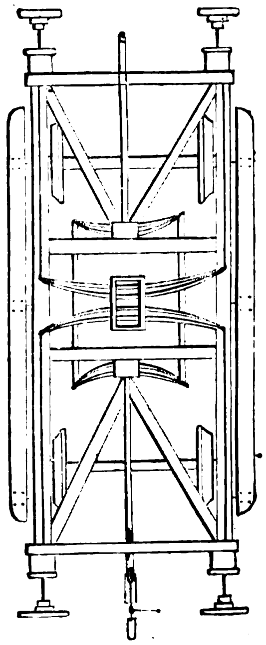
horse is connected with the boat by means of a long rope. Passenger-boats are used on some canals, moving at the rate of 9 or 10 miles an hour; they are 70 feet in length and about 5½ broad: they carry from 70 to 100 passengers, or more. Each boat is drawn by two horses, which are changed every 4 miles. They go at a gallop, and the speed is not found to injure the banks of the canal. Steam machinery has also been introduced into canal-boats with considerable effect: paddles, even supposing there were room for them, would be likely to injure the banks, so that the *screw* (fig. 524) is of great value as a means of propulsion. The section (fig. 527) does not belong to canal navigation, but is introduced to fill up the vacant space, and will be described hereafter.

It may be noticed here, that the *navvies*, who execute the earth-work of railways, derive their name from the term *navigable canals*. The tendency to abbreviate which may be noticed in a busy energetic people like the English, has converted *navigable canal makers* into the now familiar word *navvies*.

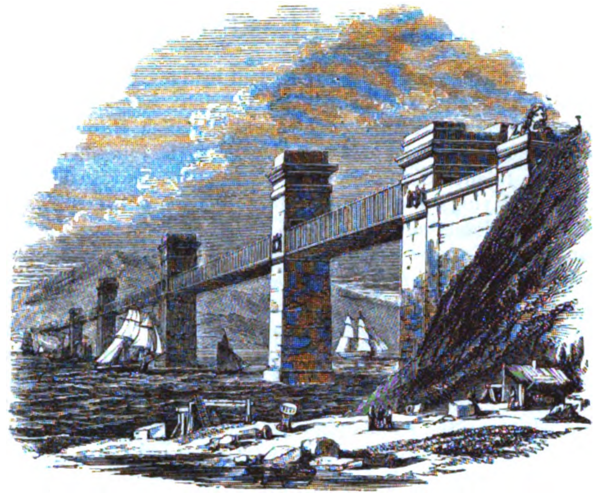
XXVII.—THE RAILWAY AND MARINE ENGINEER.

In a railway or railroad, rails of iron are laid down on a solid foundation, in order, by their smoothness, to assist the motion of wheel carriages. We are accustomed to associate a railway with a locomotive engine, drawing a long train of carriages, but a moment's consideration will show that the locomotive is not necessarily a part of the railroad, for the carriages may be, and in some cases are, drawn by horses; or they may descend inclines by their own gravity, as was practised in the colliery districts before the locomotive was invented; or the carriages may be drawn along levels and up inclines by means of stationary engines, a plan still adopted for portions of certain railways where the incline is too steep for a locomotive to ascend by itself.

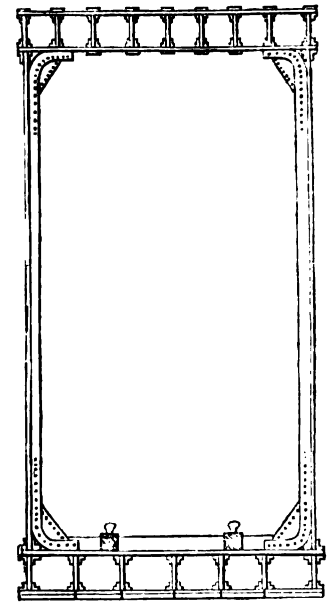
Nearly two centuries ago, the colliers in the north of England made use of wooden rails, or *tram* or *wagon-ways*, for the purpose of lessening the friction of a common road, and thus reducing the labour of drawing coals from the pit's mouth to the place of shipment. They consisted of pieces of wood embedded in the road, so as to form smooth tracks for the wheels of the wagons, and it was found that by this means the horses could perform a much greater quantity of work. They were afterwards improved by levelling the road, and placing roughly-squared pieces of wood across it, called *sleepers*, as at *A* (fig. 544). They were about six feet in length, and from four to eight inches square, and two or three feet apart. Upon these other pieces, *B*, about six or seven inches wide, and five inches deep, were fastened by means of pegs, so as to form two wheel-tracks about four feet apart. In our figure only one of these tracks is seen, as the rail is viewed from the ends of the sleepers. The spaces between the sleepers and under the rails were filled up with ashes or gravel; in this arrangement, the removal of a broken or worn-out rail injured the sleepers, and made the peg-holes too large. A second set of rails, *C*, was therefore spiked down upon the first. The wagons used on these wooden railways contained about two or three tons of coal each, and were mounted on small wheels furnished with a flange or projecting rim, which came in contact with the side of the rail and kept the wagon in its place. In places where the ascent was steep, friction was further diminished by nailing to the wooden rails thin plates of malleable iron. In descending steep inclines, or *runs* as they were called, the speed was checked by a piece of wood, called a *break* or *convoy*, which was forcibly pressed upon one or both of the wheels on one side of the wagon. The introduction of iron instead of wooden rails took place about the year 1767, and was the result of accident rather than design. The price of iron being low, it occurred to the proprietors of the Colebrook Dale Iron Works, as a means of keeping their furnaces at work, to cast the pigs in such a form as would admit of their being laid down on the wooden railway then in use at the works. This, it was thought, would save the expense of repairing the railway; but if the price of iron should rise, the rails could be taken up and sold as pigs. The road was found to be so successful that it excited some attention, and it was thought at the time to be an advantage, that vehicles could be easily turned off the track, in consequence of the absence of a guiding flange. This, however, was soon recognised as a defect when anything like speed was required on the line, and about the year 1776, the Colebrook Dale rail was improved by the addition of an upright flange, fig. 529. A rail of this kind is called a *plate-rail*, or a *tram-plate*, the latter term being derived from Mr. Outram, an extensive colliery proprietor, who patronised the new form of road, and they were first called *Outram roads*. They are still in use in mining districts, stone blocks being substituted for wooden sleepers. It will be seen that the tram-plate is a flat plate of metal with an upright flange, and it is curious that although the rails have long been changed in form, and bear no resemblance to plates, the men who attach them to what is termed the *permanent way* are still called *plate-layers*. The form of the tram-plate allowed stones or dirt to lodge upon it, thus obstructing the wheels and impeding the draught. These objections were got rid of by the introduction of *edge rails* (fig. 536), about the year 1801. They first came into extensive use at the Penrhyn slate quarries, for conveying slate to the port of Bangor in North Wales. The rail was about four and a half feet in length, and at each extremity was a dove-tail block, which fitted into an iron sill embedded in the road: the wheels had a grooved tire fitting loosely on the rail. Notwithstanding many defects in this arrangement, such was the saving of power, that ten horses were able to do the work, before required of 400, on a common road. A few years after this a better form of rail was contrived; namely, the *fish-bellied rail*, in which the lower edge was curved, so as to give the rail greater depth in the centre than at the ends or points of support. The rails were cast in lengths of three or four feet, and the ends were so contrived as to form a half-lap joint, which fitted into a cavity in a cast-iron chair, spiked down to a stone or wooden sleeper. Fish-bellied rails have been supreseded by *parallel* rails, or those which have an equal depth from end to end. Rails were further improved by making them of malleable instead of cast-iron. They are formed at the rolling mill in lengths of from fifteen to twenty-four feet, whereby the number of joints is diminished. The weight of the rails used on the first public railway with locomotives, namely, the Liverpool and Manchester, was 35lbs. per yard: whereas, the weight of the rails now in use varies from 44 to 84lbs. per yard. Fig. 543 represents a cross section of a few of the forms of rails in common use. *A A* are known as the *double T rail; B* is called a *bridge rail; C C* is a combination of the *T* rail with the broad base of the bridge rail. Fig. 542 represents the chair attached to the wooden sleeper, and the mode of fixing a double *T* rail in the chair by means of a wooden key or wedge driven in until the rail is firm. In dry weather the keys shrink and become loose, and require to be struck with a mallet to tighten them; but the loosening may be prevented by compressing the wood before it is inserted. This is done by exposing the keys, which are usually



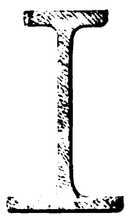
537. BUFFERS AND DRAW-BARS.



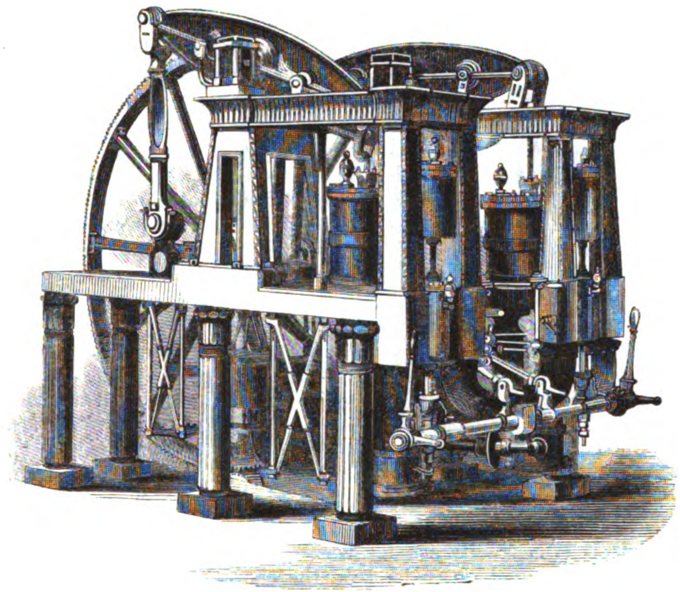
538. MENAI TUBULAR BRIDGE.



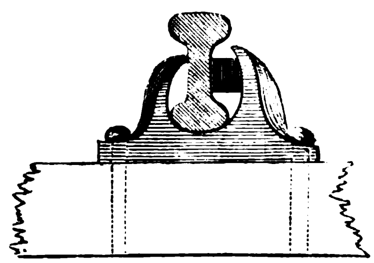
539. SECTION OF TUBE, BRITANNIA BRIDGE.



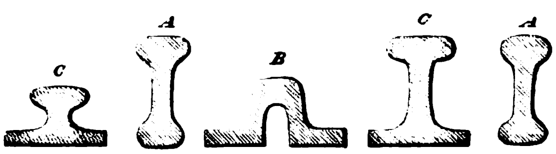
540. SECTION OF GIRDER.



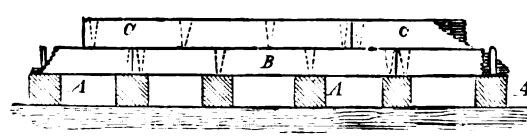
541. WORKING PARTS OF A MARINE ENGINE.



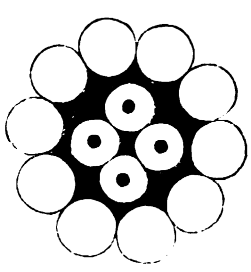
542. RAIL AND CHAIR.



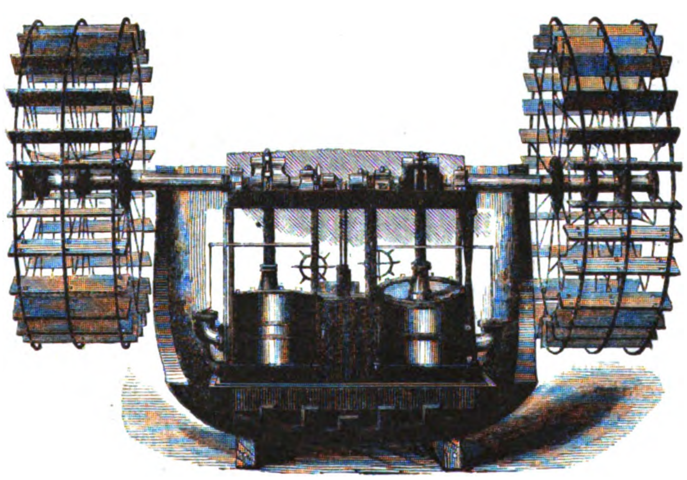
543. CROSS SECTION OF RAILS.



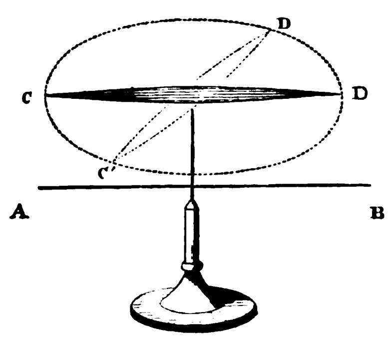
544. A, SLEEPERS; B, PRINCIPAL RAIL; C, UPPER RAIL.



545. SECTION OF MARINE CABLE.



546. MARINE CONDENSING ENGINE. (Boulton and Watt.)

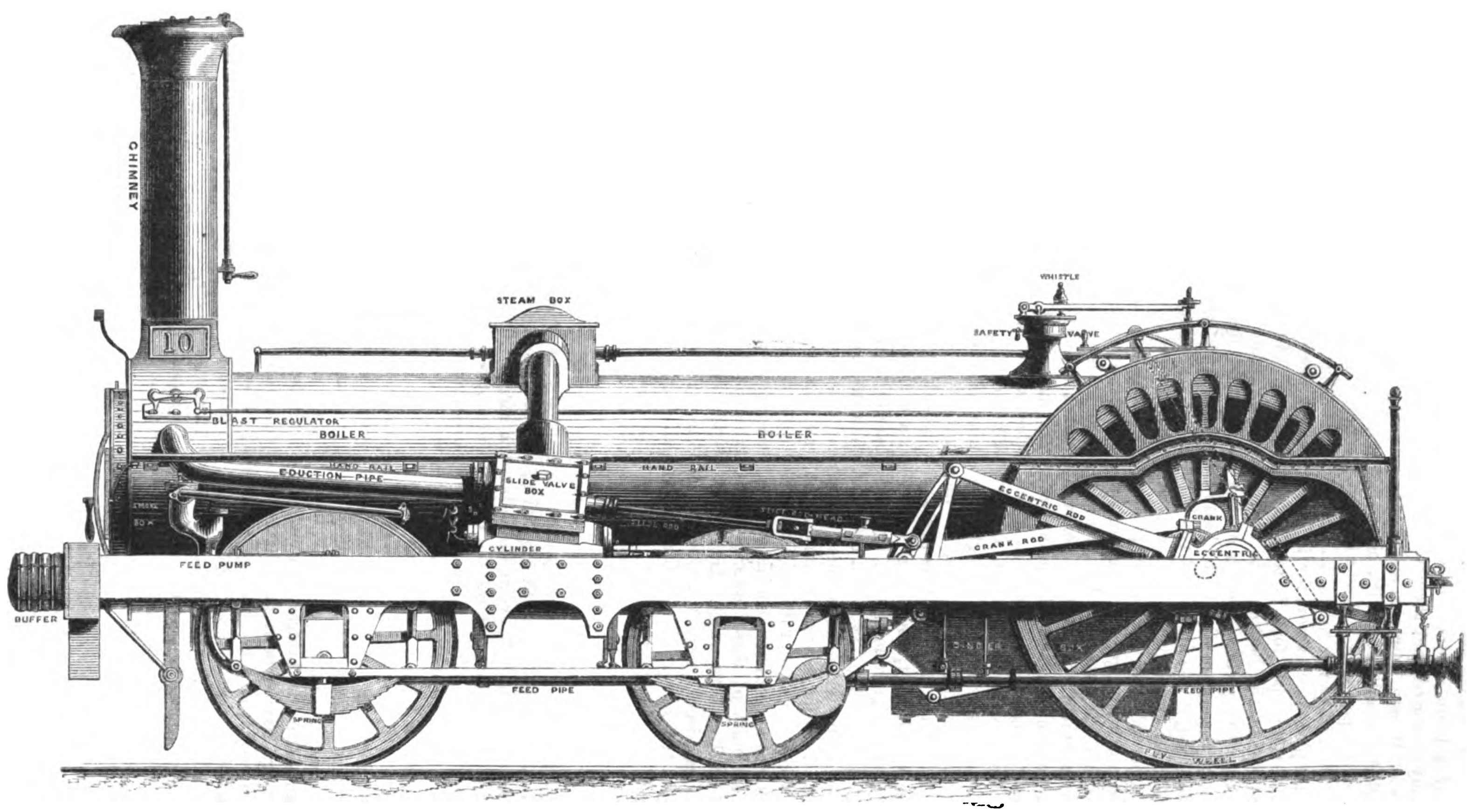


547. PRINCIPLE OF ELECTRIC TELEGRAPH.

of oak, to steam, shaping them, and forcing them through an iron block containing holes, each $\frac{3}{16}$ths of an inch smaller than the key, and tapering so as to admit the key before compression. The keys are forced through the block by the ram of a hydrostatic press.

It would be impossible in this short notice to enter into particulars respecting the surveying, levelling, and laying out of a line of railway, so that the *gradients*, or ascents and descents, shall as nearly as possible balance each other; and in no place be so steep as to interfere with the progress of a heavy train *up* an incline, or to entail any risk of accident by its accumulating velocity *down* an incline; and so to arrange, that a train in approaching a station may gently ascend, and thus have its speed checked, and in leaving a station may descend, and have its speed accelerated. It is also important that the stuff taken out of a cutting shall be used in forming an embankment, so that while, on the one hand, there is no waste of material, so also, on the other, there should not be an excess; which sometimes, nevertheless, does happen, and the company has to purchase a field or fields for the purpose of piling up whole hills of excavated material which it has no other means of disposing of. The engineer must also so arrange his line as to be within easy reach of towns and populous villages which act as feeders: at the same time the line must interfere as little as possible with the comforts, convenience, and interest of the landed proprietors, through or near whose grounds it passes. The slopes, cuttings, and embankments cannot be safely formed without much skill and varied knowledge on the part of the engineer. In stratified rocks there is a tendency of one stratum to slip upon another, and this requires the slopes to be much less steep than when unstratified materials are dealt with. This slipping is chiefly caused by the presence of water, or the action of frost between the strata; and can only be prevented by a complete system of draining, not only at the faces of the cutting, but carrying the channels backwards to collect and carry off the water that may percolate into the neighbouring soil. There must also be a complete system of surface drainage. But with all these precautions the work may have to be done more than once, and works of unexpected costliness undertaken; especially where the stratification is sand and clay alternating. When these materials are mixed, the work is safer. Stony soils, and a mixture of sand and gravel, become compact and hard. In passing through stone the excavation may have steep sides, unless it is readily acted on by frost, and then a certain amount of flatness must be allowed. Chalk may be cut with nearly vertical faces. Slopes should be preserved by being covered with turf, or sowed with grass seeds upon a surface soil. Where a soft stratum lies under stone at the bottom of the cutting, it may be necessary to remove a portion of this, and replace it by means of walls, buttresses, arches and inverts. The enormous quantity of material removed from some cuttings may be judged of by a few examples:—the Normanton cutting, at its greatest depth, is 55 feet: it contained 500,000 cubic yards of rock and *blue bind*—most of this was used in forming the Altoft's embankment—and 70,000 cubic yards were thrown out *to spoil.* No less than 8,600 men were employed, and there were eighteen fixed engines, working chiefly at the tunnels. When the work is apparently done, the *slipping* of the slopes would occasion much loss and trouble. Thus, in a cutting formed in the side of a hill in the north of England, it was calculated that about 50,000 cubic yards of earth would have to be removed: it happened, however, that the soft earth was upheld by a seam of shale, which, on being cut through, so large a quantity of earth slipped down into the line that 500,000 cubic yards had to be removed.

The formation of railways in so populous a country as Great Britain, where common roads are numerous, rivers and streams almost equally so, and where rights of way have to be respected, to say nothing of the undulating nature of the ground, have all contributed to the formation of numerous bridges and viaducts, some of which are noble specimens of engineering skill. It was ascertained some years ago, that for every mile of railway from two to four bridges had been built, many of them not mere single-arched bridges, but viaducts of hundreds of feet in length, and of great height, solidity, and cost. Among these the famous Britannia Tubular Bridge (fig. 538), on the line of railway from Chester to Holyhead, deserves especial notice. There are two such bridges, near together, formed of hollow girders or tubes: the first carries the railway over the river Conway; and about eighteen miles further on, the separation of the island of Anglesea from the main land of Carnarvonshire by the straits of Menai gave rise to the bolder structure, the central pier of which is based on a rock called the *Britannia rock*, which gives the name to the bridge. The necessity for such a structure was occasioned by the Lords Commissioners of the Admiralty, as conservators of the navigation, insisting that there should be a clear height of water way of not less than 105 feet under the bridge. On the Britannia rock a tower of masonry was erected; and at the clear distance of 460 feet from it, on either side, at the limits of the water way, another tower was built; while at the distance of 230 feet from each of these towers a continuous abutment of masonry, 176 feet in length, was constructed. The dimensions of the Britannia tower are 62 feet by 52 feet 5 inches at the base; while the height above high water level is 200 feet. The stone used for the external parts is a hard and durable limestone, known as *Anglesea marble;* while the interior of the masonry is a soft red sandstone from Runcorn in Cheshire. The Anglesea and Carnarvon towers have the same dimensions at the base as the Britannia Tower, but the height is ten feet less. The abutments are terminated at the extremities of the bridge by a projecting pedestal, on which a colossal couchant lion faces the approaching visitor. The four spaces between the Britannia Tower and the other towers, and between these and the abutments, were spanned with iron tubes; and as each tube serves only for one line of rail, eight tubes were required, namely, four of 460 feet, and four of 230 feet, the four longer ones being over the water, and the four shorter ones over the land: thus each line of way is composed of four separate tubes united together, so that, in the double line of railway, there are two parallel tubes each 1,513 feet in length. To unite each of the four sections, short lengths of tube were constructed within the towers, which, being united with the main lengths, make up each complete and continuous tube. The four shorter, or land tubes, were constructed at once in their final position; but the four main tubes were built on timber platforms on the shore, and conveyed in flat-bottomed pontoons to the towers, where they were deposited, and raised into their positions by means of hydraulic presses. In this way all the scaffolding across the straits was avoided, and the channel was only interrupted during the brief period occupied in raising each tube from the base of the towers. Fig. 539 represents a cross section of one of the tubes: the sides are parallel; the height externally is 30 feet at the centre, in the Britannia Tower, and this is reduced to $22\frac{3}{4}$ feet at the extremities of the abutments; the bottom line being horizontal, while the top line forms a parabolic curve, the the rise of which equals the difference in height, namely, 7 feet 3 inches. The clear internal height is 26 feet at the centre, and $18\frac{3}{4}$ feet at the ends. The external width is 14 feet 8 inches, the internal 14 feet, which is further reduced 7 inches by the ribs. The outside of the tubes consists of malleable iron plates, connected together by rivets, with ribs of T and L iron, besides strips of flat bar iron over the joints. The tubes are strengthened at top and bottom by means of internal longitudinal tubes or cells, of which there are eight at the top and six at the bottom. The plates vary in dimensions and thicknesses: those at the side are reduced in thickness from the ends towards the middle of the tube, and those at top and bottom are increased in the same direction. The side plates are alternately $6\frac{1}{2}$ feet and 8 feet 8 inches long; they are all 2 feet wide, and are arranged vertically: they are half an inch thick in the middle of the length of the tube, and $\frac{5}{8}$ths of an inch thick at the ends. The top plates are all 6 feet in length and $1\frac{3}{4}$ feet in width. The bottom plates are 12 feet in length and 2 feet 4 inches in width; they are in two layers. All the joints of the plate are *but-joints*, or



548. LOCOMOTIVE ENGINE.

those which meet at the edges without overlapping, the T iron being the means of holding the plates.

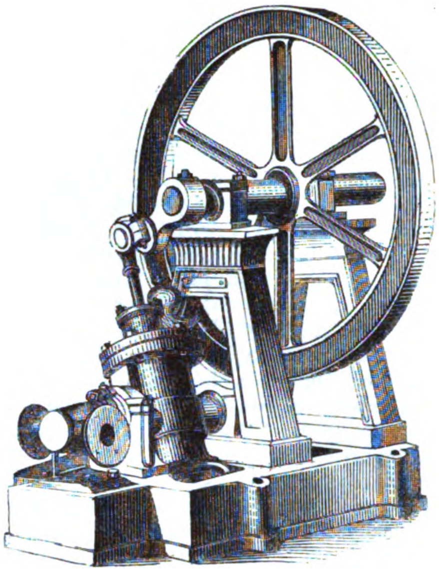
It would not be possible, without numerous drawings and elaborate description, to convey a more accurate idea of the structure of the tubes; but it may be stated, that their form was determined by the experiments of Messrs. Fairbairn and Hodgkinson, which led to the remarkable result, that with circular, elliptical, and rectangular tubes, the power of wrought-iron to resist compression is much less than its power to resist tension. This is the reverse of what takes place in cast-iron, for in cast-iron beams for sustaining weight, the proper form is to dispose the greater portion of the material at the bottom side of the beam, whereas, with wrought-iron, the greater portion of the material should be distributed on the upper side of the beam; hence, in the construction of the tube, it was found that rigidity and strength could be best obtained by throwing the greatest thickness of material into the upper side. It was further proved that the rectangular tube is very much stronger than the circular and elliptical form, a result which was extremely fortunate in facilitating the mechanical arrangements, not merely for the construction, but for the permanent maintenance of the bridge.

Fig. 532 represents the railway-bridge over the Wye, in which the engineer, Mr. Brunel, introduced a modification of the tubular principle. The rails are carried upon wrought-iron girders, resting upon enormous columns of cast-iron, to the extreme margin of the navigable channel, and from this point to the opposite shore, a distance of 300 feet, the bridge is constructed, combining the principle of the tubular with the suspension. It will be seen, by referring to fig. 532, that a tower or standard of cast-iron is erected upon the columns which stand in the bed of the river, and that a similar tower or standard of masonry is placed on the opposite shore. Two tubes of wrought-iron, 312 feet in length, and 9 feet in diameter, are laid parallel with one another upon the summits of these towers, at the height of 100 feet above the level of high water. In fig. 533, *BB* are the columns, *EE* the cast-iron tower, *N* wrought-iron girder, carrying the ends of the tubes, 11. Now, although we have here the main features of the Britannia Bridge, namely, wrought-iron tubes resting with vertical pressure on piers; the roadway is not carried through the tubes, but is suspended beneath them by means of chains attached to the ends of the tube, and passing under saddles formed on the edges of the wooden platform which bears the rails. To prevent oscillation, vertical and diagonal braces are introduced between the tubes and the roadway, and by means of adjusting screws, the chains can be stretched to any required amount. The use of the tubes is to furnish two fixed and uniformly distant points of attachment for the suspending chains, and to change their lateral pressure or tension into a vertical pressure upon the piers. In all these works where much metal is introduced, there are numerous contrivances for meeting and counteracting the unequal expansion arising from changes in temperature.

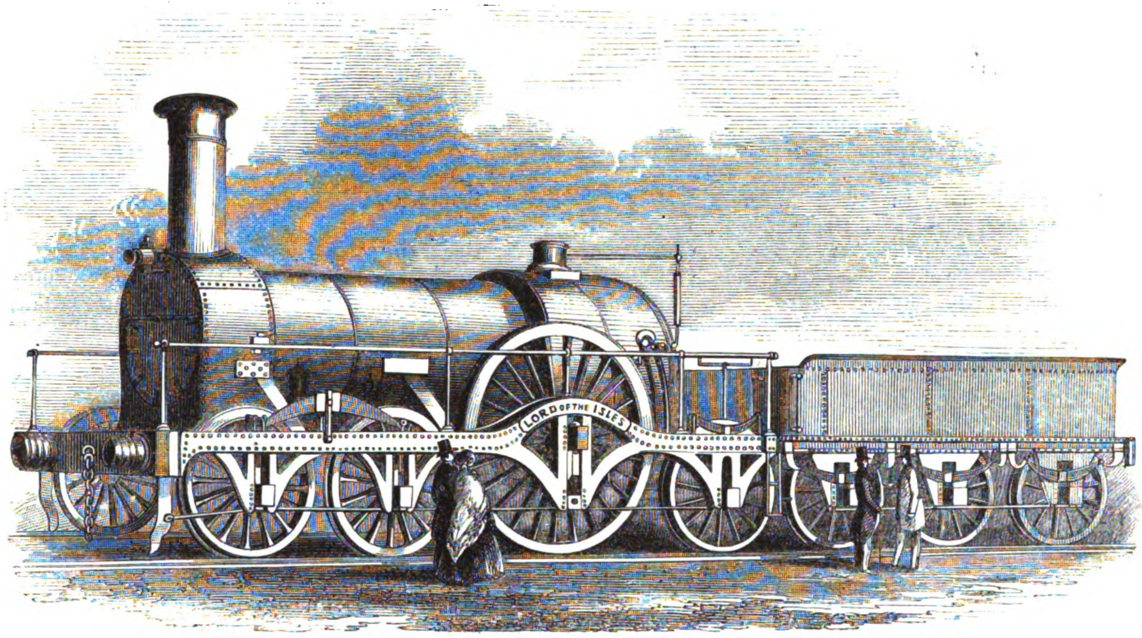
The top surfaces of the embankments, bridges, and viaducts, and the bottoms of the cuttings, having been brought to the proper level of the line of railway, the *permanent way*, as it is called, is laid down. This includes a surface covering of ballast, in which the sleepers are imbedded. If these are placed across the railway, they carry the chairs which support the rails; but if the sleepers run in the direction of the length of the railway, the rails are bolted down upon them without the use of chairs—a piece of tarred felt or vulcanized india-rubber being interposed. The ballasting may vary from 18 to 24 inches in thickness, and may consist of burnt clay or marl, gravel, broken sandstone and lias, oolite, a mixture of chalk and flints, or of sand and broken stone, cinders or small coal, &c., depending greatly upon the materials most readily procurable. The timber used for the cross sleepers is usually prepared by *kyanizing*, or impregnating it with certain saline or metallic solutions which prevent it from rotting. In laying down the rails, their joints, end to end, must not fit so closely as to prevent the metal from expanding by heat, and contracting by cold. In a range of 76° F. a 15 feet rail will vary $\frac{1}{12}$th of an inch in length. Instances have occurred in which the rails, in consequence of butting too closely together, have been raised by the heat of the sun into ridges above the level of the rail, tearing up the sleepers and doing much damage. The distance between the rails, or the *gauge* as it is called, varies in different lines. What is called the *narrow gauge* was originally adopted in the colliery railways, and furnished the standard for the earlier lines. A 5 feet gauge was adopted on some lines, which was increased to 5 feet 6 inches, and 6 feet 2 inches in some of the Scotch and Irish lines, while on the Great Western railway, the *broad gauge* of 7 feet was introduced. In *laying* down the rails, provision must also be made for conducting the engines and carriages from one line to another. For this purpose, *switches* or *turn-tables* are introduced at certain points. Switches are moveable rails placed at the junction of two tracks, and may be arranged so as to guide the train from the single track into either of the two tracks, or from either of the two into the single track. The switch revolves on a pin at one end, and at the other can be made to lie close to the inside of one of the main lines of rail, or retire a few inches from it. In fact, the switch is merely a continuation of a line of railway which diverges from the main line, and makes a small angle with it, and becomes connected, by a similar switch at the other end, with the parallel line of rails, or with the branch line, or with the siding. Fig. 531 represents a simple form of the switch, and its action will be understood by inspection. The short rail slightly bent, fixed opposite to the points, and near to the inner side of the other rail, requires some explanation. Of course the wheels of the locomotive and carriages are retained upon the rails by the flanges or ribs projecting from them. If, in approaching a switch, the flange of the wheel were either too near to the rail, or too far from it, it might either fail to catch the point of the switch, or might catch it when not intended to do so. The short bent rail, called the *guide-rail*, prevents this, for by acting on the flange of the opposite wheel, it draws the carriage over into the position most favourable for catching the points. These guide-rails occur wherever two lines of railway intersect each other, requiring the rail to be cut or divided. The turn-table is a contrivance for moving a single carriage at a time from one line of rails to another. It consists of a circular platform, usually of iron, supported on rollers, and turning on a centre without much friction, even when heavily loaded. In transferring a carriage from one line to another, it is rolled upon the turn-table, turned a quarter round, then rolled upon the turn-table of the adjoining line, and being, in like manner, turned a quarter round, it is in the proper position for being rolled upon the new track.

The enormous capabilities for traffic of a railway, depend chiefly on applying the power of steam to the drawing of wheel carriages. The idea seems to have originated with a Cornish engineer, named Trevithick, who, with his partner, Vivian, took out a patent in 1802, for a steam-engine adapted for propelling vehicles on common roads. In 1804, one of these engines was tried on a Welsh tram-road with satisfactory results. It was, however, imagined that the friction between the road and the smooth iron tire of the wheels would not be sufficient to produce attractive power, and engineers actually constructed engines with iron legs or propellers, armed with short spikes, for taking hold of the road (fig. 528). These legs had a step or stride of about 26 inches, and were made to abut alternately against the ground, by the reciprocating action of a steam-piston and cylinder. Another contrivance was a toothed rack, or series of cogs extending along the road, and a toothed wheel, worked by the steam engine, was engaged in this rack. Experience, however, showed that the mere rolling friction of a smooth wheel against a smooth rail, exerted sufficient traction for all ordinary purposes; except, indeed, sometimes in ascending inclines, or when in certain states of the weather the rails are slippery, it is necessary to scatter sand on the rails, to increase the friction. Many attempts have been made to use steam carriages on common

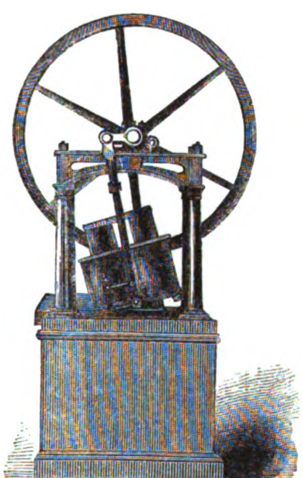
549. AMERICAN TANK ENGINE.



550. PRINCIPLE OF OSCILLATING ENGINE.



548.* LORD OF THE ISLES LOCOMOTIVE. (*Swindon Works.*)



551. MAGNETIC OSCILLATING ENGINE.

552. AN ORIGINAL BOULTON AND WATT ENGINE.

553. MODEL OF OSCILLATING ENGINE. (*Date* 1784.

roads, but the jolting caused by rough broken stones soon loosens the joints, and disarranges the parts on which the working of the steam apparatus depends. These, and many other considerations, determined the directors of the Liverpool and Manchester railway company to place, if possible, locomotive engines on their line. Accordingly, in April, 1829, a premium was offered for the best locomotive engine, capable of drawing three times its own weight, at the rate of 10 miles an hour: its weight, when filled with water, was not to exceed 6 tons, and it was not to cost more than 550*l*. It is strange to contrast this modest proposal with results which have since been realized. We now see every day engines which, with their tenders, weigh 30 tons, drawing immense loads, at speeds varying from 20 to 60 miles an hour, and costing 2,200*l*. each. In the competition above referred to, the prize of 500*l*. was awarded to Robert Stephenson, for his engine the *Rocket* (fig. 530), in which it will be seen that the cylinders (that on one side being shown in the figure) are placed diagonally, and act directly on a pin attached to one of the spokes of the wheel; so successful was this engine, that although 10 miles an hour had been fixed as the limit of speed, yet, within a very few months after the opening of the line, the journey of 31 miles from Manchester to Liverpool, was performed in one hour, and at the present day, it is not unusual for a train to move at the rate of 50 or 60 miles an hour. One of the modern forms of locomotive is represented in fig. 535. It is mounted on six wheels which do not revolve independently on their axles, as in common road vehicles, but are secured immovably in pairs, upon shafts or axles, which support the weight of the boiler and engines on brass bearings. Of these three pair of wheels, the centre pair only is *driven* or acted on by the power of the steam-engine. Engines which are built for goods traffic, usually have their driving-wheels united by *coupling-rods* with the other two pair, which must consequently be of the same diameter, so that all the six wheels are made to revolve by the motive power, thereby increasing the friction on the rail three-fold. Fig. 548 represents the various parts of the locomotive engine, so far as they can be seen from the exterior. In this it will be remarked that the driving-wheels are behind. Fig. 548* represents one of the broad gauge locomotives used on the Great Western Railway. It is capable of taking a passenger train of 120 tons at an average speed of 60 miles per hour upon easy gradients. Its force is equal to that of 1000 horses at 33,000-lbs. per horse. The weight of the engine is 31 tons, and it carries 4 tons of coke and water. The tender when empty weighs 9 tons, and its load of water 1,600 gallons= 7 tons, 3 cwt., coke 1 ton, 10 cwt. The heating surfaces are, fire-box, 156 feet; 305 tubes, 1,759 feet; diameter of cylinder, 18 inches; length of stroke, 24 inches; diameter of driving-wheel, 8 feet; maximum pressure of steam, 120-lbs. The actual consumption of fuel, with an average load of 90 tons, and an average speed of 29 miles, is nearly 21-lbs of coke per mile. Contrasted with this fine engine is the ugly-looking *Tank Engine*, used in the United States of America (fig. 549). This engine carries its own coke and water, so that there is no tender. In some cases the water is held in semicircular cisterns, placed above the boiler, and the coke in a space near the fire-box. These engines carry sufficient fuel to run light passenger trains at high velocities on short journeys. In front of the engine is an arrangement called a *cow-catcher*, for removing cows, sheep, and other obstacles from the road.

With respect to the railway carriages little need be said, except to point out the use of the *buffers*, namely, for preventing those sudden jerks, and even accidents, which would arise if the carriages were not brought very gradually to rest. Fig. 537 represents the under part of a railway carriage, with the body removed. The round knobs, or disks of the buffers, are fixed on sliding bars, the other ends of which are connected with powerful springs secured to the bed of the carriage. When the motion of the carriage receives any check, these springs receive the shock and by their elasticity destroy or absorb it. In a similar manner jerks are avoided by attaching each carriage to its predecessor or to the engine, by means of a hook formed upon the end of a bar, which slides through sockets and is con-connected with the middle of a stout spring, the ends of which are fixed. On applying the motive power to the engine, its momentum is first communicated to these springs, by which means the carriage is not suddenly and rudely, but gradually, set in motion. The buffers and draw-bars also tend greatly to diminish the lateral or rolling motion of the carriage. The carriages are not simply connected by chains, but are linked one to another by a little apparatus in which the power of the screw is brought into operation. The coupling-links consist of two oblong loops of iron, one end of each of which is formed into a nut for the reception of an iron bar, having a screw cut on the greater part of its length. The thread of this screw is so arranged, that on turning the bar, the two loops approach each other: and a lever, terminated by a heavy ball, is connected with the middle of the bar for the purpose of turning it round. The links of this apparatus being slipped over the hooks on the draw-bars of two adjacent carriages, the screw is turned until the buffers are not only in close contact, but are in some degree compressed by the force applied; and the friction between the faces of the two pairs of buffers will be sufficient to prevent, or at least to check, the tendency of each carriage to roll or oscillate laterally, independent of the other. The whole train thus becomes a continuous line, flexible indeed, but sufficiently rigid to secure a steady and uniform forward motion: the efficacy of the contrivance is sufficiently proved by the ease with which the small type of a newspaper can be read in a railway carriage. Whenever a rolling or lateral motion is perceived, it may generally be checked by turning the screw of the coupling-links.

The *breaks* are contrivances for stopping the train. They consist of blocks of wood (commonly willow), forced strongly against the peripheries of the wheels by a system of leverage. The tender is provided with a powerful set of these breaks; the guard's van has another; and the joint operation of these brings the train to a stand at the desired spot. When the sudden appearance of danger requires a very energetic application of the breaks, the driver assists their action by *reversing* his engine, that is, by causing the wheels to revolve in the direction opposite to that of his progress. These combined forces, however, occasionally fail to prevent collisions, when foggy weather or other causes have prevented the usual warnings from being given. The porters at a station facilitate the stoppage of the trains in moist weather by throwing a little sand upon the rails.

Connected with the railway system is the Electric Telegraph, which we can merely glance at in this place. It may be sufficient to remark that when a stream of electricity from a galvanic battery is conveyed along a wire, near which a magnetic needle, poised on a pivot, is placed, the needle will tend to take up a position at right angles to the wire, according to certain laws. Thus in fig. 547, let A B represent the wire, and C D a magnetic needle placed on a pivot so as to revolve freely, and transmitting a current of electricity along the wire, the needle will tend to leave its parallel position and take up another position at right angles to the wire. Now, every magnetic needle has two poles, namely, a north pole and a south pole, and these poles take up a position east and west, or west and east, according to the mode in which the wire is arranged, whether above or below the magnetic needle, and according as the current is made to flow from left to right, or right to left. Now it will easily be seen that if a needle be arranged at each end of the line, connected with each other and with the battery by means of a wire suspended by means of posts between the two stations, it would be easy to arrange a code of signals, by means of which a message could be forwarded from one station to another. For example, suppose the needle to be mounted vertically on a dial, like a clock with a single hand. If the needle point to XII. it may signify 0, if it be made to move to I. it shall mean *a*, if to XI. *e*, if to II. *i*, if to X. *o*, if to III. *u*. If made to move twice

to I. it may mean *b*, if twice to XI. *c*, and so on, and as the motions of the needle at one station are accurately repeated at the other station, we may easily imagine how they are transformed into intelligible language. If the wire which conveys the message be properly guarded it may even be laid along the bed of the ocean, and continue in constant use, as is the case with the numerous lines which diverge from this country to various parts of the Continent.

The application of steam to navigation has produced results almost equal to those of land travelling. Steam vessels of enormous size have been contrived, by means of which, long voyages are reduced to short ones, and the uncertainties which once arose from contrary winds no longer exist.

The various parts of a marine-engine are arranged with a view to compactness, as will be seen by reference to figs. 541, 546. The reader is aware that the object of this machinery is to give motion to two large wheels, called *paddle-wheels* (fig. 546), which dip into the water, and by the reaction of the float-boards against it, which act like oars, give motion to the ship. The paddle-wheels are connected with a massive iron rod, called the *paddle-shaft*, which derives its motion by means of a crank attached to the beam and connecting-rod of a steam cylinder and piston. In a stationary engine, the beam and connecting-rod, which oscillates between the steam cylinder at one end, and the fly-wheel at the other, are placed above the steam cylinder, whereas in the marine engine, the beam is placed below it. The beam, parallel motion, and connecting-rod are similar to those of a stationary engine, only they are turned upside down, and as the beam cannot be placed directly over the piston-rod, two beams and two systems of parallel motion are provided, one on each side of the engine, acted on by, and acting on, the piston and cranks, and conveying motion to the paddle-shaft by means of cross pieces which project beyond the sides of the cylinder. Fig. 527 represents a section of a marine-engine, in which X are sleepers of oak for supporting the engine, U the *furnace*, the shaded portion round it being the boiler, *i* is the *flue*, *l* the *steam-chest*, S the *steam-pipe*, CC are *slides* which open and shut by the motion of an eccentric placed on the *paddle-shaft*, and through these slides the steam is admitted from the steam-pipe to the top and bottom of the cylinder. A is the *cylinder*, B the *condenser*, and contains cold water for condensing the steam when it has served its purpose in raising or lowering the piston, when it is drawn off by E, the *air-pump*, which also discharges the water arising from the condensation of the steam; this water is conveyed into F, the *hot well*, from which the boiler is renewed. TT is the *feed-pipe* for conveying the water, L is the *piston* connected by the parallel motion to the *beam* H, which works on a centre near the base of the engine. The other end of the beam drives the *connecting-rod*, M, which extends upwards and works with cranks. The dotted lines show the beam on the further side of the engine, a similar beam similarly placed, and working on the same centre, must be understood to be on this side connected with the piston. *Y* is the *safety-valve*, QR the framing by which the engine is supported, *hh* are cocks for pouring off salt water from the boiler. The salt in sea-water forms a sediment in the boiler, which not only diminishes the heat, but corrodes the iron, so that it is necessary from time to time to blow out the salt.

In what are called *oscillating* engines, the beam is got rid of, and power is saved by getting a more direct action. In this form there are two cylinders which move backwards and forwards by the action of the crank on the piston; that is to say, the piston, as it rises and falls, causes a revolution of the crank, which in its turn moves the piston and cylinder backwards and forwards. There is a fixed air-pump between the cylinders. There is also a pump connected with the machinery for supplying the boiler with water from the sea, so long as the engine is working, and when the vessel is stopped for any length of time, a smaller engine, called a *donkey*, is set to work to keep the boiler full, The screw, fig. 524, is now usually preferred to the paddle-wheels. The screw consists of a shaft turned round by the steam-engine, but differently placed, for it projects from the stern in a line with the keel of the ship: the vanes, which extend from it obliquely, in turning in the water, strike against it in such a way as to force the ship forward.

The principle of the Oscillating Engine is represented in fig. 550. It is one of the simplest examples of a direct rotatory action obtained from the combination of the piston-rod and the crank. The idea is by no means a new one, as was noticed at the time of the Great Exhibition with reference to the model (fig. 553), which was made by Murdoch in 1784 for the purpose of illustrating Watt's patent for making the cylinder work on its axis. Fig. 551 is an Oscillating Engine in which, instead of the cylinder and piston worked by steam oscillating, we have an electro-magnet, consisting of two hollow cylinders of soft iron, surrounded by coils of wire, in which two pistons of soft iron work, also surrounded with coils of wire, forming a second electro-magnet. When the current from a galvanic battery is passed through the wires, the cylinders and the pistons attract each other with considerable force. The pistons are attached to a crank on the driving shaft by means of a connecting-rod, and the magnetic cylinders are made to oscillate at each stroke by a contrivance for making and unmaking the magnets on either side of the axis alternately. There have been numerous proposals for working machinery and driving locomotives by means of electro-magnetic power. There are, however, many objections to it, and so long as coal is plentiful it will probably be found more economical to employ it directly in raising steam, than indirectly in smelting zinc, which has to be consumed in the galvanic battery.

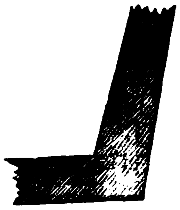
XXVIII.—THE SHIPWRIGHT.

A LARGE number of trades are concerned in the building and finishing of a ship; but the man who shapes and puts the timbers together is called a *shipwright*, and of him we shall chiefly speak. Ship-building is both a science and an art: it is a science, inasmuch as some of the grand principles of nature are brought to bear upon the form of the vessel, and the positions and proportions of its various parts, such as will best promote stability in the water, and speed in moving through it, &c. Ship-building is an art, inasmuch as it depends on certain rules of construction, which are subject to variation according to experience or the peculiar notions of the naval architect. Then, again, the mode in which a ship is built depends greatly on the kind of service which she has to perform. A man-of-war is always furnished with the same kind of stores, whereas the lading of a merchant-ship is liable to frequent variation; the cargo may be heavy at one time, and comparatively light at another. With a heavy cargo the ship may be immersed two or more feet deeper in the water than with a lighter one; and the draught of water in a collier may vary at different times as much as 4, 5, or 6 feet. As the ship becomes lightened, she loses in stability, and may acquire a dangerous rolling motion. These and many other causes render the theory of ship-building complex and difficult. We do not intend to refer to them except to remark, that the architect, having carefully decided as to the form and dimensions of the ship with reference to its special object, draws three plans, or sections in planes, passing through the largest portions of the ship, and known as the *sheer plan*, the *half-breadth plan*, and the *body plan*. The sheer plan divides the ship into two equal parts, by a plane passing through the middle line of the vessel, from the middle line of the stem or fore-boundary, to the middle line of the stern-post or after-boundary. The half-breadth plan describes half the widest and longest level section in the ship, or that of a horizontal plane, passing through the length of the ship, at the height of the greatest breadth. The body plan describes the largest vertical section athwart the ship. The drawings are usually on a scale of ¼ inch to 1 foot, and when they are all settled and agreed on, enlarged copies are made to the full size of the objects represented, and they are traced with chalk on the floor of a room, called the *mould loft*. This is called *laying-off*, and its object is to furnish the workmen with the exact shape and proper positions of the principal pieces of timber of the intended ship. The floor is usually equal to half the length of the ship, and the whole height of the hull in addition. When the plan is laid down, the timber ribs or *frames* are marked in their proper places, and pieces of plank ¾ inch thick are cut to the forms of the timber; these are called *moulds*, and they are used as patterns for cutting or converting the timber, certain marks made on the moulds indicating the directions in which the sides of the timbers are to be cut.

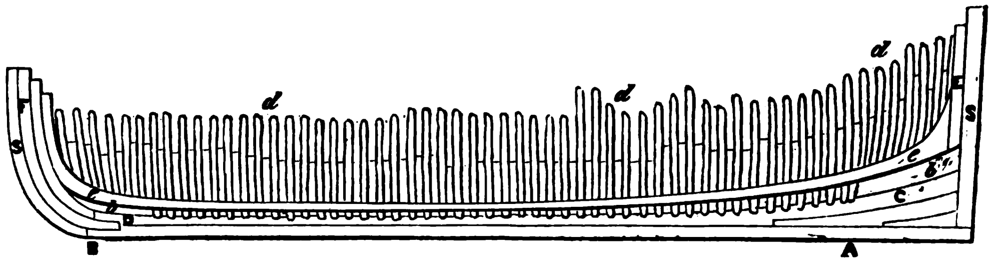
The ship is usually built on a piece of ground called the *building slip*, forming an inclined plane towards the water into which the ship is to be launched. The first thing to be done is to arrange on the slip a row of oak-blocks, 3 feet high and 4 feet apart, in the direction of the length of the intended ship. On these blocks is laid the *keel* A B, fig. 555; it is the lowest timber of the ship, and upon it the whole fabric is raised: the wood is usually of elm, which resists the water well, and its fibres are sufficiently tough to receive the numerous fastenings and bolts which pass through it. The keel usually consists of a number of pieces of timber scarfed together. Below the main keel, which in a large ship may be 20 inches square, pieces of elm from 4 to 6 inches thick are worked, forming what is called the *false keel*, the object of which is to give the ship greater immersion, and in the event of her grounding in shallow water, the false keel by being forced off may free the ship from danger. At each end of the keel, and extending towards its middle, timbers called the *dead-wood* are placed as at C, D; and the upper surface is cut into a curved form *b b*, with which line the bottom of the ship's body is made to coincide. At each end of the keel is set up a post; that at S being the *stern-post*, and that at S′ the *stem-post*: the latter is curved near the bottom. In large ships the stem is made up of 3 pieces; called the *upper*, *middle*, and *lower* pieces: they are united to each other and to the fore-end of the keel by means of scarfs, or with coaks and copper bolts; the scarf which unites the stem with the keel, being termed the *boxing*. The stern-post should be of oak, and if possible in one piece, on account of its having to support the rudder; the mode of inserting the keel of the stern-post in the after-piece of the keel by means of tenons and mortices, is shown in fig. 554. The ribs or *frame* of the ship form a large collection of timbers; such as *floors*, *cross-pieces*, *futtocks* and *top-timbers*. The sides and upper portion of the keel and dead-wood are cut for the reception of the floor timbers, which are placed across the keel, as shown in section *a*, *b*, *c*, *d*, fig. 557, *e*, *f*, being the middle line of the ship, and in order to keep it steady in crossing the keel, a piece of timber called the *rising wood*, *g*, *h*, *i*, *k*, is worked into the seat of the floor and into the keel. In some cases the floor is steadied by means of a coak, passed both into the floor and into the keel, as at *e*. For the sake of economy the frame is sometimes arranged as in fig. 558; in which two *half floors* meet in the middle of the vessel, and alternate with *short floors* or cross pieces. The timbers which join the cross pieces or floors are called the *first futtocks*, dowels or tenons of hard wood being placed in the heads and heels of the respective pieces, as in fig. 560. In merchant ships the first futtocks run down to the side of the rising wood or dead-wood; so as to leave what is called a *water-course* of the breadth of the keel or of the rising wood, as in fig. 559. The *second futtocks* are placed on the heads of the half floors, and the *third futtocks* on the heads of the *first futtocks*, the *fourth* on the heads of the *second*, and the *fifth* on the heads of the *third*: the *top timbers* are placed on the heads of the *fourth timbers*, and these, with the top timbers and *lengthening timbers*, form the frame. In merchant ships the heads and heels of consecutive timbers are united by means of *chocks*; as in fig. 561, which economises the timber.

The distance between the frame timbers varies in the Royal Navy from 2 ft. 6 in. to 2 ft. 9 in. The timbers above the surface of the water are nearly straight, but below it they are of various curvatures to suit the form of the ship. Within the stem is a timber called the *apron*, fig. 564: it is a continuation of the fore dead-wood, as the stem is a prolongation of the keel. Its use is to strengthen the stem, and allow for the reception of the plank of the bottom, and the heels of the foremost timbers. In order further to support the stem, the *stemson*, fig. 555, is worked in. The inner post is a continuation of the after dead-wood, and forms a foundation for the reception of the plank, and receives the heels of the extreme after timbers. The floor-timbers are secured in their places by the *keelson*, fig. 562, which is square in form, and of the same width as the keel *k*, *l*; *c d* are the heads of the cross-piece, *e* the butt joint of the half floors, placed on one side of the middle line to allow a coak *f* to be inserted clear of the butt *e*, and the copper keelson bolt *a b* is passed also on one side of the middle line, through the keelson, cross-piece, and keel. In large ships two additional keelsons, G G fig. 566, called *side* or *sister keelsons*, from 30 to 50 feet long, are bolted to the floor timbers, sufficiently near to one another for allowing the *step* or foot of the main-mast to rest upon them.

The timbers are covered on the outside and partly on the inside with planks of oak from 3 to 6 inches thick, secured by

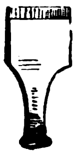


554. INSERTION OF STERN POST IN KEEL.

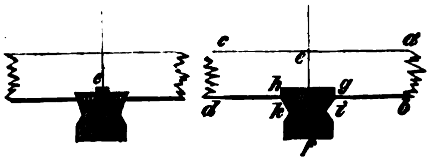


555. ELEVATION OF SHIP'S TIMBERS.

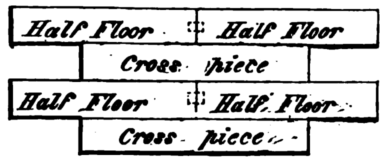
555*. THREADS OF OAKUM.



556. MALL.



557. FLOORS, TIMBERS, AND KEEL.

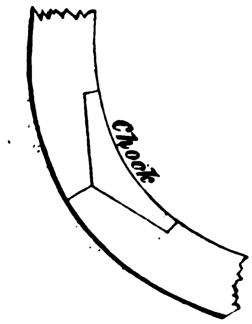


558. ARRANGEMENT OF FLOOR TIMBERS.

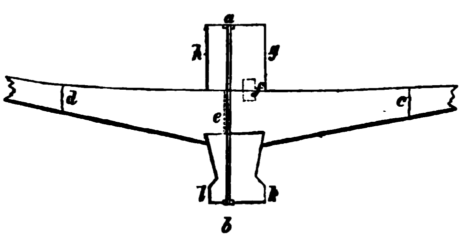
559. FUTTOCKS AND DEAD-WOOD.

560. CONNEXION OF FLOOR WITH FUTTOCKS.

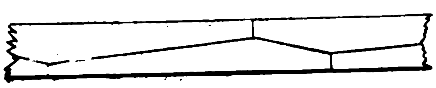
563*. SHIP YARD.



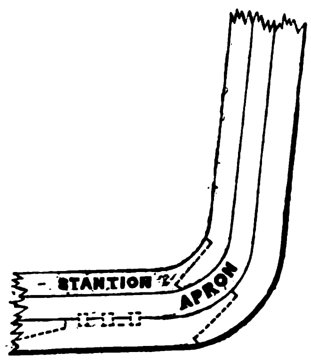
561. UNITING TIMBERS WITH CHOCKS.



562. FLOOR TIMBERS, KEELSON, AND KEEL.

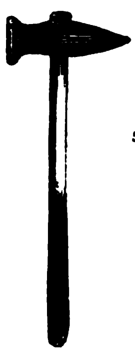


563. ARRANGING PLANKS, TOP AND BUTT.



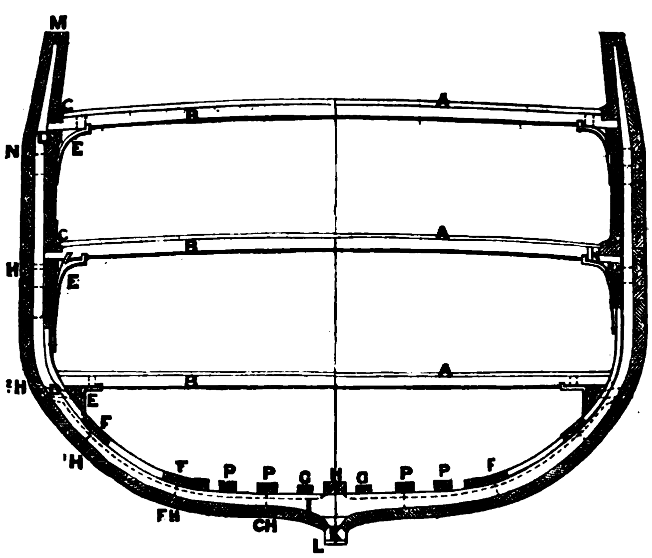
564. POSITION OF APRON.

564*. COPPERING-HAMMER.



564**. MALLET.

565. PITCH POT.



566. MIDSHIP SECTION.

566*. CAULKING.

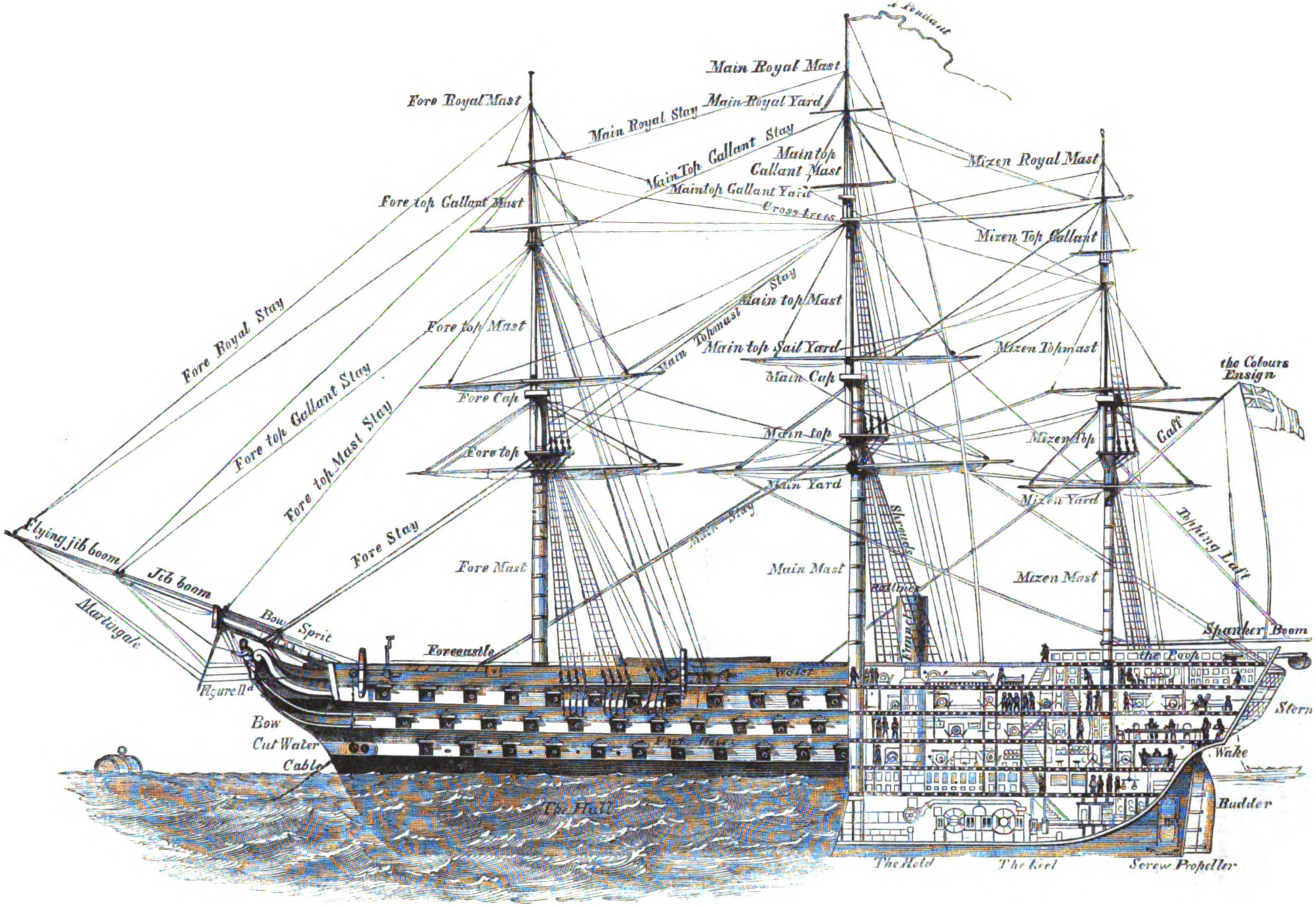
means of bolts and trenails, or plugs of oak. Before the planking is applied, the spaces between the frame timbers are filled up with pieces of wood 3 inches deep, and the spaces between the exterior and interior pieces are also sometimes filled up with cement, so that should the outside planking be torn off the vessel would still float. There is a tendency, after the vessel has been some time in the water, for the keel to become curved, in consequence of the falling of the extremes and the rising of the middle of the ship. This *hogging*, as it is called, has been met by a diagonal framing or trussing, and also by introducing iron plates, for tying the timbers to each other.

Fig. 566 represents a mid-ship section, in which A A represent the *decks* or *platforms*, B B the *ship's beams*, C C *water-ways*, D *shelf-pieces*, E *iron knees*, F *strakes*, F H, I H, &c. *heads* and *heels* of the frames, G *limber strakes*, H *keelson*, I *fillings* between the timbers of the frame, K *keel*, L *false keel*, M *rough trenail*, N *wales* or *thickest planking*, P P *bearers* for the boilers of a steam vessel. The beams B which receive the decks of the ship, are supported at their ends on longitudinal ribs called *shelves*, which form portions of the internal planking of the frame. In order to apply the planking or *skinning* as it is called, the frame is set perpendicular by dropping a plumb line from certain points to the middle line of the ship. That part of the skinning called *bends* or *wales* is commonly of English oak called *thick stuff*, and varies from $4\frac{1}{2}$ to 10 inches in thickness. To make up this thickness the planks are worked *top and butt*, fig. 563, to suit the tapering shape of the timber, the lower or butt end of one plank being brought to the top of the upper or thinner end of another plank. The planks are not fixed at once to the frame, but are hung thereto with the holes bored, and are so left in order that the air may dry up the juices of the wood; the fastenings are wooden trenails or copper-bolts. The first band of inner planking from the keelson is called the *limber strakes*, G fig. 566, but a space is left between the side of the keelson and the lower edge of the strakes, which serves as a gutter for drainage. The gutter is protected from the dirt of the hold by limber boards or plates when of iron, otherwise the dirt might pass into the pump-well and choke the pumps. A large ship has usually three strakes on each side; next to the strakes are the planks F, which are worked over the heads of the floor timbers and the heads of the first futtocks to prevent these timbers from being forced in. The beams may be compared to the rafters of a house, supporting as they do the floors or decks; they are not flat, but set to a *round*, or portion of a large circle, so that the decks when placed on them may throw off the water to the sides, where holes called *scuppers* are placed to convey it away. The inside planking immediately under the shelves is called the *clamps*, and that over the water ways the *spirketting*, the latter being so secured by dowelling as to prevent the beam ends from rising off the shelf pieces, when the ship is rolling in a sea way. Next comes the framing of the deck, in arranging which provision must be made for doorways, hatches, and mast-holes. These last are of larger diameter than the masts by double the thickness of the wedge which holds the masts in position. The framing for a mast-hole with wedges consists of *fore and aft partners*, *cross partners*, and *corner chocks*. The hatch-ways or door-ways from one deck to the other are formed of four pieces, the two placed fore and aft being called *combings*, and those athwart ship, *head ledges*. These last rest on the beams, and the combings have pieces of wood called *carlings* under them and extending from beam to beam. The ladder-ways are framed in a similar manner, and on the upper deck are skylights, or framings for the *galley* or cooking range similarly worked. The framing of the ship also includes the *riding bitts* in the fore, for receiving the cable when the ship is riding at anchor. The *ports* or oblong holes in the sides in which the guns are worked are closed in stormy weather by *port-lids*, which are hung with hinges on the upper side and held up by ring bolts, a piece of glass being let into them to give light when closed.

The joints or seams of the outer planking are made water-tight by means of spun threads or layers of oakum forced into them, for which purpose the seams of the planking may be opened by sharp iron wedges called *reeming irons*. The oakum is driven into the joints by means of *caulking irons*, which are also sharp iron wedges. The seams are next *payed* with melted pitch applied with small mops, and that part of the ship which is to receive the copper sheathing is levelled by laying in spun yarn and *payed up*, or covered over with a mixture of pitch and tar. The decks of the ship are also caulked with oakum, and the weather decks are payed with marine glue.

The ship being now made water-tight is ready for launching. It has already been stated that the slip-way on which the ship is built is inclined towards the water, but in order that she may be slid down into her own element without damage, the weight of the ship (which in a large man-of-war may be as much as 2,600 tons for the hull alone) is transferred from the slip-blocks to a supporting frame-work or *cradle*. This cradle is formed upon two inclined planes or *sliding ways*, one on either side of the keel. The cradle is supported by what are called *bilge ways*, while the sliding ways are blocks of wood supporting planks so as to form an inclined plane. Outside the bilge ways, and to prevent them from being forced out by the weight of the ship, is a timber called a *riband*, and this forms the abutment of the after end of a piece of timber called the *dog-shore*, the fore-end of which butts against large *cleats* on the bilge ways, and these cleats retain the ship on the sliding ways until everything is ready for launching. Thus the bilge ways form the support of the cradle, and the cradle is the truck or carriage which bears the ship into the water, while the sliding ways are the inclined planes down which the bilge ways move. The amount of inclination to be given to the sliding ways is determined by the size of the ship, the rise and fall of the tide, and the inclination of the building slip. The slide beyond the slip is laid during the recess of the tide, and a number of other arrangements having been made, the upper sides of the sliding ways and the under sides of the bilge ways are payed over with melted tallow, and when this is cold, soft soap or oil is added in patches. The bilge ways are then turned in, and the cradle is adjusted to the bottom of the ship, when on the morning of the launch, large wedges called *slices* are placed inside and outside the bilge ways, and men with heavy hammers are stationed near them. By driving in these wedges the hull is raised in the cradle, and its weight taken off from the blocks on which the after part of the vessel rested during the building. The blocks are then removed. The forepart of the cradle is not attached very firmly to the bottom of the ship, but the weight rests partly on the foremost building blocks, which just before the launching are split out from under the ship, so that just before high water she is seen from aft, supported on two comparatively narrow ribands. The ship is christened by dashing wine against her bows or forepart, and the signal "down dog-shore" being given, the last obstruction is removed, the ship glides into the water, the cradle falling from her and rising in loose detached pieces to the surface.

The launching is a good test as to the soundness of the naked planking. The next process is *sheathing*, for which purpose the ship is floated at high water into dock, and being placed on the blocks prepared for her, the dock gates are closed, and the water at the fall of the tide is let out through drains or culverts. The ship is secured by means of *guy ropes*, and by shores of timber, extending from the sides of the dock to those of the ship. The copper sheathing is in sheets, 4 ft. by 14 in. while the thickness is indicated by the weights of the square foot, which vary from 32 oz. to 16 oz. In applying the sheathing, the lower edges of the upper sheets are made to lap over the upper edges of those below, and the after end of each sheet to lap over the fore end of the one following it. The 32 oz. copper sheathing is used round the ship at the height of the load water line for four *strakes* or sheets down, and on the bows down to the keel. The 18 oz. and 16 oz. sheathings are usually placed between the main and false keels, to protect the former from the worm



567. NAMES OF THE VARIOUS PARTS OF A SHIP.

should the latter be torn off. A 120-gun ship requires 4444 sheets of copper for the sheathing. The copper is liable to constant corrosion from the action of sea-water; but it may be protected by using zinc-headed nails in fastening it on, when a voltaic current is formed, and the zinc is dissolved in preference to the copper.

A ship's mast is usually formed of several pieces: the central piece is in the form of a many-sided prism, and other pieces are attached to its sides by means of a projection in each, which is let into a corresponding channel in the central piece, or blocks of hard wood may be let into the central and the attached pieces, the whole being secured by iron hoops placed at intervals. The masts resist the pressure of the wind by means of *shrouds* and *backstays*, which are secured to the sides of the ship. The fore-mast is usually set upright, but the main or mizen-masts *rake*, or incline aft.

The large collection of ropes used for supporting the masts and for extending or reducing the sails, are comprehended in the general term *rigging*. This may consist of *standing rigging*, such as *shrouds*, *stays*, and *backstays*, used for supporting the masts, and occupying a fixed position in the ship; while the *running rigging*, including *braces*, *sheets*, *halliards*, *clue lines*, &c., is used for arranging the sails, and is passed through various blocks, arranged about the masts, yards, shrouds, &c. The *lower rigging* is used for the lower masts, and the *topmast rigging* includes the topmast shrouds, stays and backstays.

The arrangement of the masts and rigging for the most part determines the class of vessel. Thus a *ship* has a *fore*, a *main*, and a *mizen* mast, with a *topmast* and a *top gallant mast* to each, while the yards in sailing before the wind are braced *square;* that is, in horizontal positions perpendicular to the length of the ship. When the mizen mast carries no top sail, or top gallant sail, we have a *barque*. A *brig* has no mizen mast; a *schooner* has two masts but no top sails, and the sails are in vertical planes, passing through the keel. A *sloop* or *shallop* has only one mast with a mainsail, the plane of which is usually in a fore and aft position. All these varieties have each a *bowsprit*, carrying a *fore staysail*, and a *jib sail*. A *line of battle ship* carries 70 or more guns. A *frigate* has usually two decks, and carries from 36 to 60 guns. Sloops and corvettes carry from 4 to 20 guns; brigs, cutters, brigantines, ketches, schooners, and barques, do not carry more than 10 guns each.

Vessels are now frequently constructed of iron: they are formed with ribbed frames at intervals, and with longitudinal hoops of iron, and they are covered with iron plates attached to the ribs by means of bolts and rivets. The lower part of the interior is sometimes divided into separate air-tight compartments, so that should the bottom be pierced in any one part, the water would be confined to that compartment.

As a ship of war usually indicates its size by the number of its guns, so a merchant ship shows its size by its tonnage; a term which really refers to the number of tons of sea-water which a vessel would contain. Now as there are 35 cubic feet of sea-water in a ton weight, the interior volume of a ship expressed in cubic feet divided by 35, gives the tonnage. But as the ship when she floats in still water, with only her equipments and stores on board, occupies a plane passing through the ship at the level of the water, and known as the *light-water plane*, and as this differs from a similar horizontal plane passing through the ship when laden, and known as the *load-water plane*, the volume of that part of the ship between the two planes, expressed in cubic feet, and divided by 35, gives the weight of the ship's cargo.

The foregoing details will give some idea of the complicated structure of a ship. Should the reader desire further information, he will find in a cheap and accessible form in the Rudimentary Treatises on Naval Architecture by Mr. Peake, Assistant Master Shipwright of H.M. Dockyard, Woolwich: we would especially refer to Parts II. and III. of this work, published separately, containing the "Practice of Ship-building."

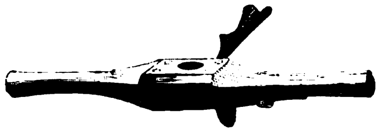
XXIX.—THE COACHMAKER.

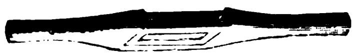
If the various descriptions of craft used for conveying people over seas and rivers be numerous, so that it requires a special study to acquire their names and leading characteristics, not less varied are the wagons, coaches, and vehicles used for land carriage; to say nothing of sledges, sedans, palanquins, and litters, which preceded the introduction of the wheel; we have carts with solid wheels, or slices cut off from the trunk of a large tree; carts and wagons of wood bound with hide, and a flooring of the same material; carts tilted with canes and straw neatly wattled. We then have improvements in the wheel, and the introduction of springs for hanging the carriage and diminishing concussion; the introduction of two additional wheels with facilities for turning the vehicle. To trace all these varieties, and the improvements which have been from time to time introduced, would require a very long history; whereas all we propose to do is to give a few details respecting the trade of the coachmaker, and these must be imperfect, seeing how greatly the trade is subdivided, for in building a coach, we have to consult the *coach-body-maker*, the *carriage-maker*, the *coach-smith*, the *coach-plater*, the *coach-beader*, the *coach-carver*, the *coach-trimmer*, the *coach-lace-maker*, the *coach-lamp-maker*, the *harness-maker*, the *coach-wheelwright*, the *coach-painter*, the *herald-painter*, and some others.

The materials used in a coach, are timber, iron, plated metal, leather, woven materials, paint, varnish, &c. The first operation in building a coach is to make a design, such as will show the forms and proportions of the various parts, the arrangements made for the comfort and convenience of the traveller, and the general effect of the whole. Thus the designer is to a certain extent an artist, and as new forms and fashions are constantly arising, there is usually a certain constant amount of work for him. He has also to make the working drawings, which are sketched on a black board on the same scale as the work to be executed. The mode of proceeding then very much resembles the plan adopted in ship-building, where, as already stated, *moulds* are formed in thin pieces of wood, for directing the shipwright in his work. In like manner, the *mould* of a coach is prepared by cutting out a number of thin pieces of wood according to the chalk marks on the board, to serve as a guide to the workman in cutting out the timbers, and this is the more necessary, since all the lines of a coach are curved, and many of the curves have a complex character.

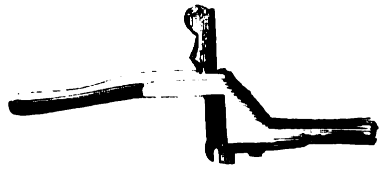
The timber having been selected, it is cut up at the saw pit, first in the round, and afterwards for converting, that is, it is first cut into planks, and then roughly cut at another pit into the forms indicated by the pattern pieces. The most valuable wood used by the coach-builder is hedge-row ash, well adapted for the frame-work on account of its tough fibrous character, and its not

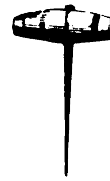

568. GIMLET.

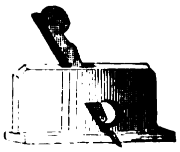

569. GROOVING ROWTER.

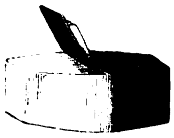

570. SPOKESHAVE.

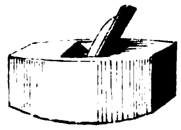

571. SIDE ROWTER.

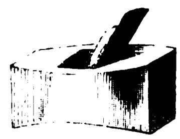

572. PISTOL ROWTER.

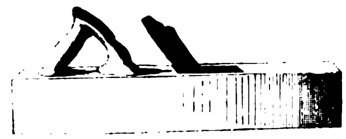

573. DRAW PIN.

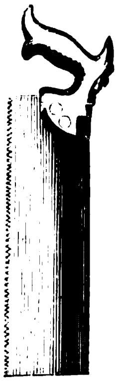

574. PLANE.

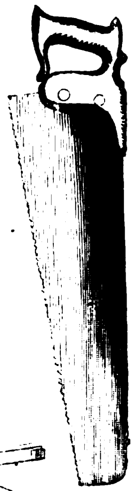

575. HAND PLANE.

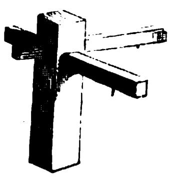

576. CONVEX PLANE.

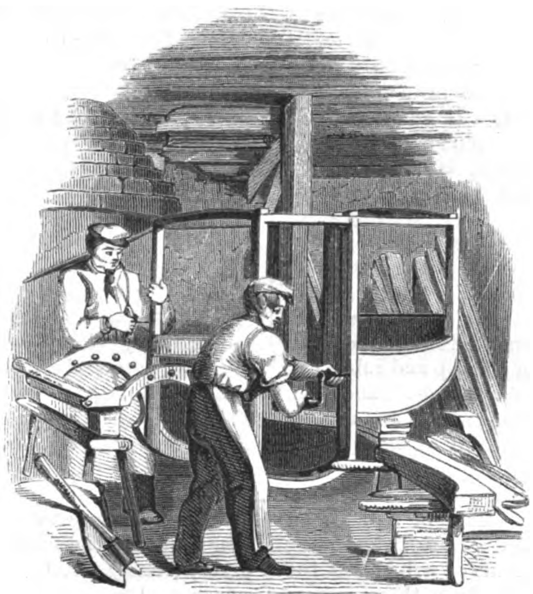

577. CONCAVE PLANE.

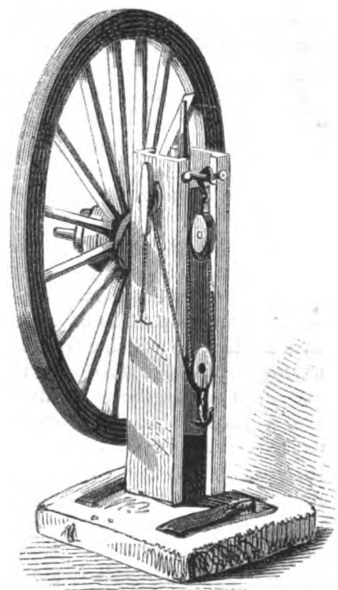

578. PLANE.

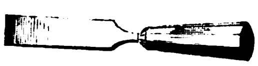

579. TENON SAW.

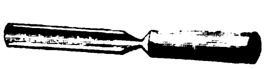

580. HAND SAW.


581. GAUGE.


582. COACH-BODY MAKERS AT WORK.


583 WHEEL HORSE.

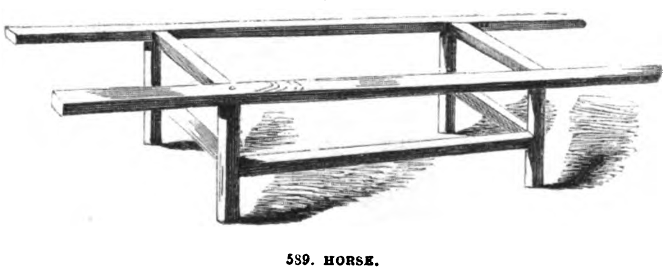

584. CHISEL.


585. GOUGE.


586. HOLDFAST.


587. SQUARE.


588. SIDE AXE AND CHIPPING BLOCK.


589. HORSE.

590. PAINT BRUSHES.


591. PAINT POT.

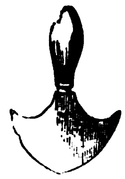
being liable to warp. Beech is not used in the best coaches; elm is used for planking and also for the naves of wheels, and oak is preferred for the spokes of wheels and for those parts which require to be strong and durable. The panels are formed of Honduras mahogany, and sometimes of cedar, while deal and pine are also used in the floor and roofing, and a few other kinds of wood, such as fustick, lance-wood, birch, sycamore, chestnut, and plane, are employed to a limited extent.

The coach-builder applies the term *carriage* to the frame-work which lies beneath or around the body, and serves to support it, and to connect it with the wheels, pole, &c., so that there are two distinct sets of workmen, one known as *body-makers*, who construct the frame-work and panelling, &c., and the other as *carriage makers*, whose work is rougher. The pieces of the frame-work of ash having been cut to shape, are put together for the body, and as the meeting edges are seldom at right angles to each other, the joints are made by means of glue, bolts, nails, screws, tenon and mortice, lap-joints and grooves; constantly referring to the mould-pieces in executing the work. There is not much peculiarity in the tools, for they resemble those of the joiner. It will be seen, however, that the *planes* (fig. 576, 577,) are adapted to convex and concave surfaces. There are also various forms of *rowlers* (fig. 569, 571, 572,) or planes for forming grooves, for levelling the bottoms of cavities, &c. The *spoke-shave* (fig. 570,) is a small plane iron something like a pen-knife, set in the middle of a frame which can be used with both hands. It works easily in the direction of the grain, and is used for shaping and smoothing small rounded surfaces. The curved form is given to the panels by wetting the wood on one side and heating it on the other.

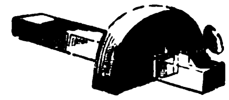
When the various parts of the body have been put together, and the carver has added the beadings and mouldings required, a thick coat of paint is laid on; but before this, for the best work, the roof and a portion of the sides, front and back, are covered with leather, for which purpose a large sound hide is selected, and having been well soaked it is thrown over the top and rubbed or pressed down on the roof, until it lies perfectly smooth and even. The workman then takes one of the hanging pieces and rubs it flat to one of the sides, trimming it off at a beading which separates the panels from the quarters or upper panels. He proceeds in like manner with the other parts, flattening the surface without making any incision in the skin; for this would be liable to let in the wet and ruin the carriage: by means of skilful rubbing and working, he is able to get rid of the folds or wrinkles at the corners: by working the leather gradually from these corners towards the centre of the sides and back, the puckers disappear, and the leather tightly adjusts itself to the form of the body. When the leather is properly adjusted, the painter sets to work, and it is a long business before he completes it, as many as from twelve to fifteen different coats being applied. There are from six to eight coatings of copal varnish, and the result is as beautiful and durable a polish as can be met with in any kind of wood-work.

It is scarcely necessary to do more than refer to the fine Spanish cloths, the rich plain and embossed silks, the embossed leather, the lace, and the cushions employed in finishing the interior of a coach. The lace may be of worsted or of silk, or of both materials combined, and it is used as a binding or edging: what is called *pasting lace* is used for concealing rows of tacks, and *seaming lace* for concealing seams and edges. The roof, sides, and other parts of the interior are made level by means of wadding and canvas, and are lined with cloth or silk. Cushions are stuffed with horsehair, and covered with cloth, silk, or morocco leather. The bottom of the coach and the folding steps are covered with carpet.

While the coach-body makers are at work upon the body, the carriage makers are engaged on their part of the structure. The springs have to be formed, either as *single elbow springs*, *double elbow springs*, *under springs*, *nut-cracker springs*, *C springs*, *S springs*, &c., while the smith has to form various pieces of iron-work, such as *plates*, *loops*, *stays*, *hoops*, *clips*, *bolts*, *steps*, *treads*, *joints*, *jacks*, *shackles*, &c.; some of which, however, belong to the body. The making of the wheels constitutes the distinct trade of the wheelwright. A wheel consists of a centre or *nave*, radii or *spokes*, and a circumference or the *felloes*. The nave is a short block of elm pierced with a hole for receiving the axle-tree: the spokes are rods of oak radiating from the nave, while the felloes are circular segments of ash, attached to the ends of the spokes, and uniting so as to form a circle: the felloes are all bound together by an iron hoop or *tire*. The nave is brought to shape in a turning lathe, and having been pierced for the axle, the mortices are chiselled out for the ends of the spokes. The mortices must be cut with great care, so as to give the spokes, or rather the wheel, a *dishing* as it is called, or slight concavity on the outer surface, so as to give more room for the coach body, and to avoid splashing. The oak for the spokes is cut into lengths of four feet, which are then shaped by hand; when the nave, being placed in a kind of socket in the floor, the spokes are driven in by means of a mallet. This is called *speeching* or *spoking*. The felloes being properly shaped by means of pattern boards and cutting tools, are drilled each with four holes; two for receiving the cylindrical ends of the spokes, and two for joining the felloes, end to end, by means of dowels of oak. After this, the whole is bound firmly together by means of a solid iron hoop, which is put on at a red heat, and well beaten, while it is being rapidly cooled by pouring water upon it. The tire in cooling contracts in dimensions and holds the frame-work tightly. Iron pins are driven through the tire and felloes, one on each side of every joint, and the points are riveted inside the felloes. The projecting parts of the nave are also furnished with iron hoops for the sake of strength. The axle consists of three parts; namely, the two *arms* which pass into the naves of the wheels, and the *bed* or central part which connects them together. The nave is lined with a well-fitting iron box for receiving the axle with little friction, and also for containing a reservoir of oil. The axle is usually turned at a lathe, and is then case-hardened, that is, its surface is converted into steel. White metal, or *albata*, or white brass, is largely employed for beading, plates, locks, hinges, handles, rings, buckles, &c., but iron plated with thin sheet brass is also used. A good deal of the semi-cylindrical beading is made by drawing sheet metal through an iron or steel plate, and the concave side of the beading is afterwards filled in with soft metal and is furnished with points for fixing it. For the best work the beading is formed of sheet copper, coated with silver.


592. ROUND KNIFE.

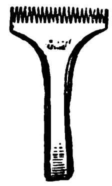

593. HEAD KNIFE.


594. CUTTING GAUGE.

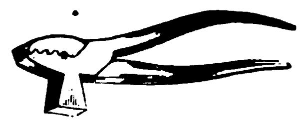

595. DEAD PUNCH.


596. HAND KNIFE.


597. SPOKESHAVE.


599. PRICKING IRON.

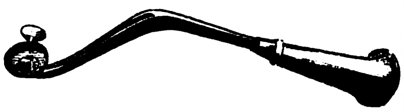

600. COMPASSES.

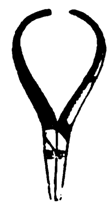

603. PINCERS.


604. PUNCH.

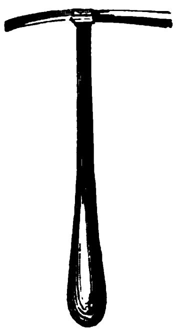

601. EDGING IRON.


602. SEWING AWL.


605. SCREW CREASE.


606. PLIERS.


611. CLAMPS.

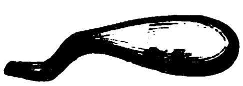

607. HAMMER.


608. DOUBLE CREASE.


613. WORKSHOP.


609. SINGLE CREASE.


610. NAIL CLAW.


612. HAND IRON.

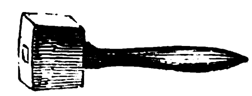

614. FILE.

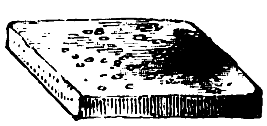

615. RULE.

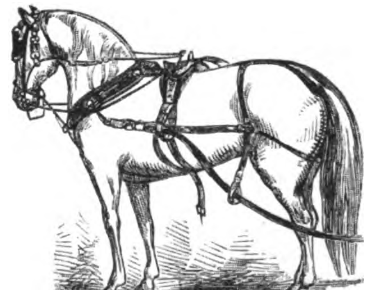

616. NEEDLE AND THREAD.


617. VARNISH POT.


618. SPONGE.


619. MALLET.


620. LEAD PIECE.


621. HARNESS.


622. PACKING AWL.


623. SEAT AWL.

XXX.—THE SADDLER AND HARNESS MAKER.

It seems always to have been the custom to place some kind of cover on the horse's back previous to riding him. The first kind of covering was probably the skin of a wild beast slain in the chase, and as a nation advanced in luxury we read of costly coverings of cloth or of leather. Even at the present day, eastern nations are accustomed to decorate their saddles with pearls and precious stones. The word saddle appears to be derived from the Latin verb *sedeo*, to sit, and it is of importance to enable the rider to sit easily. Saddles do not seem to have been introduced into England previous to the reign of Henry VII, and we do not read of the woman's saddle, or *side saddle*, as it is called, previous to the reign of Richard II.

The saddle consists of a wooden frame called a *saddle tree*, which is furnished by a man called the *tree maker;* and as the fitting of the saddle depends in great measure on the form of the tree, it is not uncommon to measure the horse's back for it, just as a man is measured for a pair of shoes. On this frame is laid a quantity of horsehair, wool, or other packing material, which is covered over with leather, neatly nailed to the wood. In order to keep the saddle steady on the horse's back a *crupper* is sometimes used, passing under the animal's tail, and *girths* to prevent it from turning round. The rider's legs are supported by a pair of stirrups, one of which is used to assist the rider in mounting; while to prevent the saddle from galling the horse's back, a saddle cloth is sometimes added. The tools used by the saddler are cutting knives, hammers, pincers, &c., represented in the figures. But the saddler's ironmonger supplies him with stirrup irons, various kinds of buckles, bits for bridles, and other steel or brass furniture necessary for the harness, while the *horse's milliner* makes roses for bridles, and other articles used in ornamented caparisons. The saddler prepares the various kinds of bridle for coach and chaise harness. The embroiderer and the lace maker supply him with various ornamental articles.

It is said that the best saddles and harness are made in Great Britain. There are various kinds of saddle, such as the *hunting saddle*, the panels of which must be well beaten and brushed to save the horse from a sore back, and a short saddle must not be allowed, that is, it must not be under sixteen inches from pommel to cantle. The *running saddle* is small with round skirts; the *Burford Saddle* has the seat and the skirts plain; the *pad saddle* has burs before the seat, and sometimes bolsters under the thighs. In the *French pad saddle* the burs come wholly round the seat. In the *portmanteau saddle* there is a cantle behind the seat to keep the portmanteau from the rider. The *war saddle* has a cantle and bolster behind and before, also a fair bolster. The *pack saddle* is a saddle arranged for carrying loads.

XXXI.—THE FARRIER.

It is the business of the farrier to shoe horses, and his name is derived from the Latin word *ferrum*, iron, which is the material of which the shoes are made: indeed, the old writers call him *ferrier*, and *ferrer*.

The necessity for protecting the feet of the horse by means of iron shoes, arose in great measure from our system of road-making; the stony, flinty surface being very different from the wide, sandy, or grassy plains which the horse in his wild state is accustomed to. We read in ancient history that before the use of metal shoes, the hoofs of horses were often worn away during long and fatiguing journeys, so that the animal became useless. Various materials have been used as horse-shoes, such as leather, plaited hemp, and even straw. These were used in the sense in which we employ the term shoe, or rather sock, for they were drawn on to the foot instead of being fastened beneath it. The present practice of shoeing horses appears to have been introduced into England about the time of the Conquest.

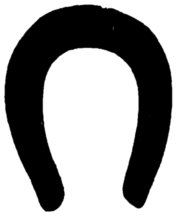
The necessity for horse-shoes will appear from a moment's consideration of the structure of the hoof. This consists of a hard *crust* or rim, nearly surrounding the lower part of the foot: it is formed of horn, or horny fibres, and has no sensation. The crust is attached to the lowest bone of the leg, called the *coffin bone*. Within the cavity of the hoof is a wedge-shaped substance called the *frog*: this was formerly supposed to be a sheath for the protection of the inner and softer parts of the foot, and farriers, impressed with this idea, made the shoe thick enough to raise the frog from the ground. It was suggested, however, that the function of the frog is to share in the pressure on the foot, and by its elasticity, to relieve or distribute the pressure on the hoof. Experience seems to have confirmed this view, so that instead of making the heel of the shoe so high as to raise the frog from the ground, it is now usually formed so as to allow it to press on the ground.

Some horses secrete the horny material of the foot more abundantly than others, so that about every three weeks the *drawing knife* (fig. 649,) of the blacksmith has to be applied, and the shoes replaced. It was formerly the custom to pare down the hoof by means of an instrument called a *butteris;* a custom which is happily almost obsolete. Moisture is beneficial to the health of the horse's foot, so that when circumstances require it, it should be stopped with damp tow. In hot stables among dry litter, the hoofs become dry, hard, and brittle, so that in shoeing large pieces will split off, even though very fine and thin nails be used. A remedy for this is exercise in the open air (which cures so many evils among ourselves), and turning the horse out to graze.

The best wrought iron should be used for horse-shoes: sometimes small pieces of steel are attached to the part most liable to wear. The width and thickness of the shoe vary with the strength and age of the horse, the purpose for which he is employed, whether for draught, riding, &c. The weight of the shoe varies from 12 to 20 ounces for carriage and saddle horses, while for the heaviest draught horse it may be some pounds. The shoe is forged from a rod of bar-iron of about an inch and a quarter in width, and three-quarters of an inch in thickness. The farrier's shed (fig. 645), resembles in many respects the

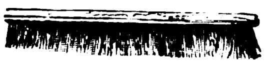
624. NIPPERS.

625. PUNCH.



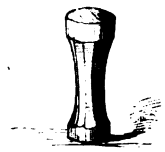
626. SHOE.

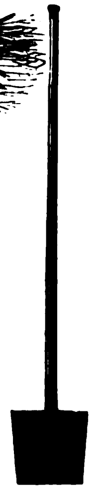
627. STAMP.



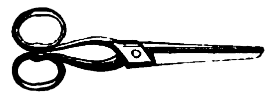
628. BRUSH.

629. NAIL.



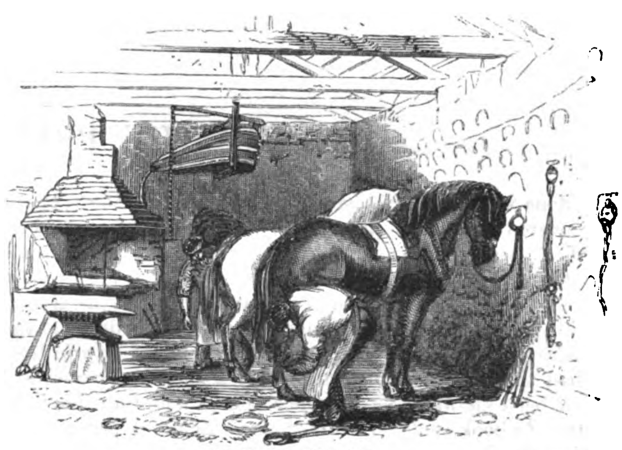


630. STAPLE. 631. POINTING STAKE 632 FULTER. 633. DAMPER 634. SLICE. 635. POKER. 636. LADLE. 637. SPATULA. 638. TONGS.

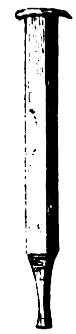


639. SCISSORS.

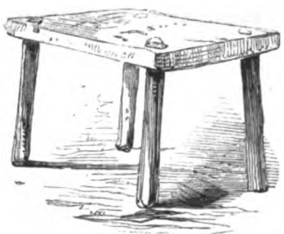
640. BUFFER.



645. FARRIER'S SHED.

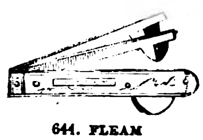


642. PRETCHEL.

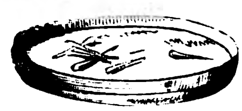


643. STOOL.

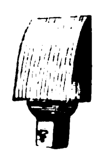
641. REACHING IRON.



644. FLEAM



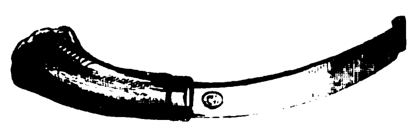
646. NAIL BAG.



647. SWAGE.

648. SHOEING HAMMER.

651. ANVIL.



649. DRAWING KNIFE.

650. TURNING HAMMER.

652. RASP.

blacksmith's shop. The forge is a kind of furnace for heating the rods, and is enclosed with a hovel which leads into the chimney; while at the back, against the fire-place, is a thick iron plate, for receiving the nose of the bellows. The bellows is above and behind the forge, and is worked by means of a rocker, with a string or chain fastened to it, which the workman pulls: one board of the bellows is fixed, so that by drawing down the handle of the rocker the upper movable board rises, but being loaded with a weight, sinks again, and thus produces a blast of air in the pipe. In front of the forge is a trough of water, which is used for wetting the coals, cooling the *tongs*, (fig. 638,) with which the hot iron is held, and also for hardening the iron by suddenly quenching it. The *anvil* (fig. 651,) is sometimes made of cast iron, but should properly be of wrought, and faced with steel. The common smith's anvil consists of the *core* or *body*, the four corners for enlarging the base, the projecting end, containing a square hole for the reception of a *set*, or *chisel*, or *swage*, (fig. 647,) used in cutting pieces of iron, and the *beak*, or conical end, used for turning pieces of iron into a curved or circular form. The anvil is usually placed on a loose wooden block, such as the root end of an oak tree.

In forging a horse-shoe some parts of the work require a hammer of peculiar form, the head being almost spherical: it has two flat faces; one rounded face for the inside of a shoe, and one very stunted *pane* at right angles to the handle, used for drawing down the *clip* in front of the horse-shoe. What is called the *turning-hammer* is shown fig. 650. Eight or nine holes are punched in the shoe to receive the nails by which it is fastened to the foot, and there is also a groove forged in the shoe to prevent the heads of the nails from projecting.

A horse-shoe does not last more than a month, and when the work is very rough, only a few days. The shoe cannot be too light, provided it does not bend. Some prefer the toe to be cut short, and nearly square, with the angles just rounded off, and it is said that if a nail be driven in at the toe the horse is liable to stumble.

A *farrier's pouch* consists of a leathern bag, containing *drivers*, *nippers*, *shoes*, *nails*, &c. for new shoeing. The *shoeing hammer* is shown fig. 648, the *horse-shoe nail* fig. 629, and the *rasp* with which the work is smoothed off, fig. 652. The other tools scarcely require notice. The *fuller* (fig. 632) is a chisel held by a hazel rod, to prevent concussion, and is used for cutting off the shoe after it has been forged at the end of the rod. The farrier formerly practised the elements of veterinary surgery, and even now undertakes to bleed a horse, which he does by means of the *fleam* or *lancet* (fig. 644).

XXXII.—THE PRINTER.

The Germans have done well to erect a statue in honour of the man who first discovered the art of printing with movable types of metal; for there is assuredly no invention which has conferred greater benefits on mankind, or more honour on the author of it than this. Before the introduction of this art, in the middle of the fifteenth century, books could only be produced by the costly method of copying by hand with pen and ink upon parchment. A book had then the value of a house, or a small estate, and persons have been known to pledge their houses and lands for the safe return of a book confided to their care. Before the invention of printing, the Bible was not even in the hands of the rich, and it is doubtful whether they could have read it, had they had the opportunity. Even in the religious houses, where one would expect to find men deeply versed in the Sacred Scriptures, it was rare to find a complete set of them. One monastery might possess a book of the Old Testament, another one of the Gospels, a third one of the Epistles, and so on; so that a man might travel over wide districts without having an opportunity of reading more than fragments of the Bible. The richer monasteries had attached to them a writing-room, called the *scriptorium*, and it was held to be a pious work for a man to devote himself to copying the Scriptures and *illuminating* them, that is, adorning with drawings and devices, often with coloured pigments and gold, the vellum page. Many of these illuminated books are still to be seen in large libraries, and they fetch very high prices.

Books then being so costly, we do not wonder that an ingenious man should have endeavoured to produce them with greater facility: the wonder is that we do not read of many attempts previous to the time of Gutenberg. His first trials were made in the city of Strasburg, and his first idea was probably suggested by the *block-books*, which had for some years been common. These consisted of small books of pictures, each page consisting of a figure of a saint, or of a group of persons, with inscriptions under them, or running round the page. In order to produce one such page, a block of wood was taken, and a drawing having been made upon it, an engraver cut away all the white portions of the wood, so as to leave the lines of the drawing or of the writing in relief. This is precisely the process by which wood-engravings are produced at the present day, such, for example, as illustrate the book now in the reader's hands. The page so engraved, having been covered with ink, a piece of damp paper was placed upon it, and in this way it was passed through the press. A number of such pages having been thus produced, they were arranged in twos, pasted back to back, and when bound or stitched, formed a block-book. Many such books are to be found in public and other libraries, and they are eagerly sought for by bibliographers.

Now Gutenberg's first idea was a happy one. It occurred to him that if the letters thus drawn and engraved on wood were separated by cutting up the block, they could be arranged so as to form a page of reading, and when a number of impressions had been taken, could be re-distributed, and composed into another and a different page; for it is obvious that any particular page of a block-book could only be used for that page, and when a different page was wanted, the whole process of drawing and engraving had to be gone over again. Gutenberg, however, found that his wooden type soon split and warped, and became useless; when it occurred to him to cut or chase the separate letters in metal, but this was found to be as costly as the labour of the scribe. He therefore attempted to cast his letters separately, in plaster moulds, but the results were so rough and uneven that he abandoned the idea in despair. Having spent all his own money, and a good deal of other people's, he applied for assistance to a rich goldsmith of Mayence, named Fust or Faust, who, it must be admitted, took advantage of the necessities of the poor inventor to drive a hard bargain. Wealthy men are often not more liberal to poor inventors of the present day. Fust does

GREAT PRIMER.—This is sometimes called *Bible text*, as it is seldom used in printing any other books than the large folio Bibles. The French call it *Great Roman.*

ENGLISH.—This is used for printing Bibles, large books, and the body of hand-bills. The French and Dutch call it *St. Augustine;* it is supposed, therefore, that this sized type was first used by those nations in printing the works of that writer.

PICA.—This is the standard by which all the others are measured. It is more generally used than any other sort, especially in printing works of a high character. The French and Germans call it *Cicero*, it having been originally used by them in printing the Roman orator's epistles.

SMALL PICA.—This is the favourite type for novels. It is called *brevier* by the Germans, and *philosophie* by the French.

LONG PRIMER.—This sort is generally used for printing small books, or large books with close pages. The French call it *little Roman*, and the Germans *corpus*, it having been used by them, in the first instance, for printing the *Corpus Juris.*

BOURGEOIS.—This type is very much used, and generally forms the largest type employed in printing newspapers. Bourgeois is a French word, signifying a *citizen*, and the name is applied to it in England as expressing the common use of the type. The French themselves call it *gaillarde.*

BREVIER.—This is employed in printing small cheap books, and for notes to larger type. It is supposed to have derived its name from the practice of using it to print breviaries, or Roman Catholic church books. The French call it *little text*, and the Germans *maiden letter.*

MINION.—This type is very largely used in printing newspapers, as well as in small prayer-books and bibles, and pocket editions of other works. The Germans call it *colonel*, and the French *mignonne*, or favourite.

EMERALD.—This is a small kind of Minion, used chiefly in Newspapers and Bibles, and only lately introduced.

NONPAREIL.—This type is so called because it is far more beautiful than any other sort. It possesses all the beauty, without losing the distinctness of the larger sorts.

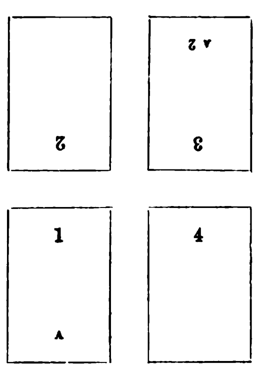
RUBY. This is, like Emerald, an interpolation in the original order of types. It was, at first, a Nonpareil body with a smaller face. The French have no type which corresponds with it.

PEARL.—This is only used for miniature books and notes, and is legible only to persons possessing strong sight.

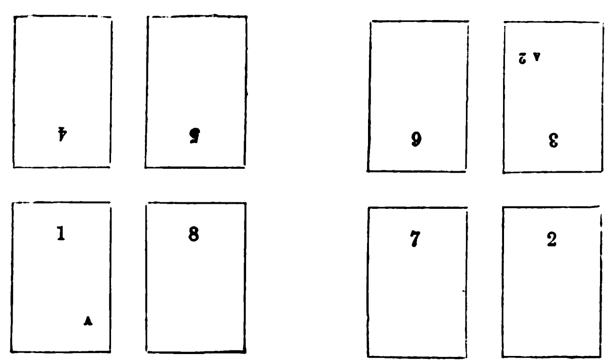
DIAMOND. This is the smallest sort of type in general use, and was first cut by the Dutch. A book printed in this type is indeed a curiosity, like the Lord's Prayer written on the size of a sixpence. The letters are so small, that 2,800 of them are contained in a pound weight. We may add, however, that a type still smaller was cast by M Didot, a French printer.

BRILLIANT This is the smallest type cast in this country It is chiefly used for marginal notes and contents of Chapters to the Diamond Bibles Strong or rather near sighted eyes are required to read it, and microscopic eyes to arrange the letters for printing It is cast only by Miller and Richard of Edinburgh and London

A SHEET OF FOLIO, CONTAINING FOUR PAGES, TWO ON EACH SIDE.

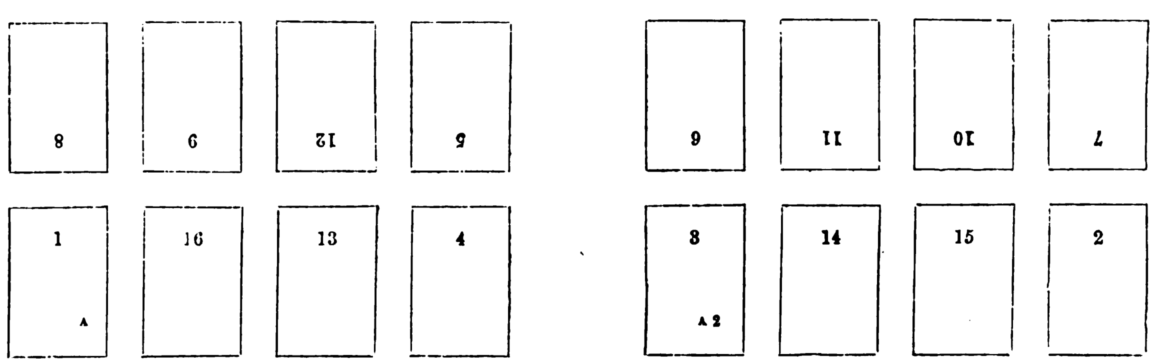


A SHEET OF QUARTO, CONTAINING EIGHT PAGES, FOUR ON EACH SIDE.



OUTER FORM. INNER FORM.

A SHEET OF OCTAVO, CONTAINING SIXTEEN PAGES, EIGHT ON EACH SIDE.



OUTER FORM. INNER FORM.

not appear to have assisted the invention, except by appropriating it, but he called in one, Peter Schœffer, a scribe, and promised him, it is said, the hand of his daughter if he could bring the invention to bear. The three partners deliberated long and anxiously on the subject, and made many experiments, when at length it seems to have occurred to Schœffer to form for each letter a punch of some metal, such as could be cut by hand while soft, and when finished, be hardened. By means of this punch a sunken impression could be made in copper, or some such metal, so as to form a *matrix* which would reproduce the letter any number of times, by the ordinary process of casting. Such is, in fact, the modern practice of type-founding. The plan turned out to be perfectly successful. A fount of type was produced in this way, not of the Roman letters which we are accustomed to in books, but resembling the writing-hand of the period. For it must be remarked, that although these three men, Gutenberg, Fust, and Schœffer, were instruments in the hands of Providence for working out a purpose for the good of mankind, they were not aware that such was the case, but had their own interests keenly in view. They kept their processes strictly secret, and hence, in order not to excite too much inquiry, they made their printed books to imitate as far as possible the written books of the period. Before, however, their first book was printed, the partners had disagreed, and Gutenberg left the concern, himself in debt, and all his printing materials deeply mortgaged to Fust. Within eighteen months of this event, namely, in August, 1457, Fust and Schœffer produced the Psalter, printed in large type; and in 1460 was published the celebrated Latin Bible. No sooner was this work accomplished than an event occurred which, humanly speaking, would seem to have been disastrous to the young art, namely, the siege of Mayence in 1462, the breaking up of its trade, and the dispersion of its artisans. Among the workmen thus dispersed were the journeymen of Fust and Schœffer, and wherever they went they spoke of the marvellous success of the new art, and competent men took it up, so that within six years of the publication of the Psalter, there were printing presses in several considerable towns, and within fifteen years this great privilege had extended to every considerable town of Europe.

The plan and limits of this work do not allow us to enlarge upon the history of printing; but we have thought it right to give the above details on account of their singularly instructive and suggestive nature. Men are too apt to forget that inventions which have a first-rate importance on the destinies of mankind are not of sudden growth, but are prepared by long antecedents, by which the world is made ripe for the invention, and is able to appreciate it. Such an invention might have been useless or even mischievous at an earlier period; but coming just at the right time, as in the case of printing, when men's minds had begun to awake from the intellectual slumbers of the dark ages, could appreciate the beauties of Roman and Greek literature, and above all were preparing in various ways for a purer faith, which was consummated by the glorious reformation, no time could have been so fitting for the invention as this, which was to place a Bible in every man's hands, and enable him to give a reason for the faith which was in him. Considering all these things, shall we not say of the Printer as the prophet of old said, when speaking of the labours of the ploughman and the sower, "For his God doth instruct him to discretion, and doth teach him."—(Isaiah xxviii. 26.)

The first step in the art of printing is taken by the type-founder. His art is one of great complexity, not only on account of the large number of sizes of type in common use, but also the large variety of *sorts* or characters belonging to each size. There are two kinds of founts in use, the one for *book-printing*, and the other for *job-printing*, the latter including such work as hand-bills and posters. Book-types include eleven or twelve regular bodies, from *Great Primer*, which is the largest, to *Diamond* which is the smallest type used for printing books.

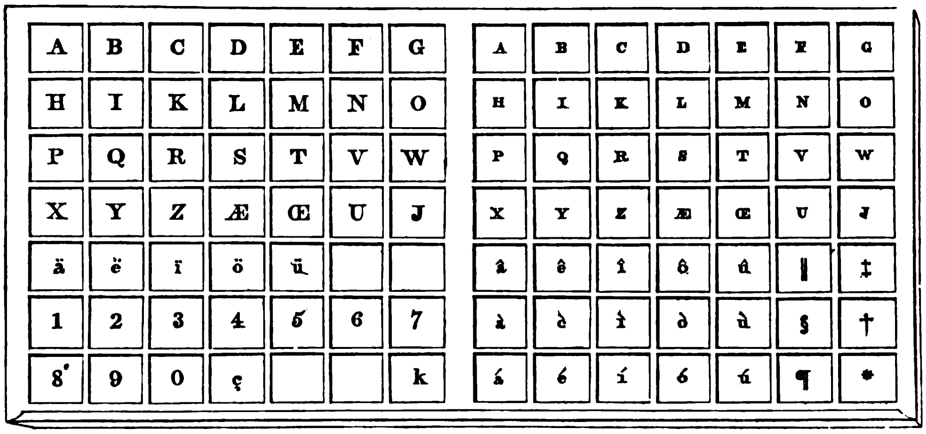
A set of types was anciently called a *fund;* it is now called a *fount.* The different letters bear a fixed proportion to each other. Thus a fount containing 8,500 a's will have 1,600 of b; 3,000 of c; 4,400 of d; 12,000 of e; 2,500 of f; 1,700 of g; 6,400 of h; 8,000 of i; 400 of j; 800 of k; 4,000 of l; 3,000 of m; 8,000 of n; 8,000 of o; 1,700 of p; 300 of q; 6,200 of r; 8,000 of s; 9,000 of t; 3,400 of u; 1,200 of v; 2,000 of w; 400 of x; 2,000 of y; 200 of z.

The numbers vary in this way, because some letters are more used than others. It has been found, for instance, that 200 z's are sufficient where 12,000 e's are required. The capital letters of a fount are also proportioned to each other similarly to the other letters. To these must be added the spaces, which are small pieces of metal used to separate the words: being shorter than the letters, the ink in printing does not touch them, and, therefore, they make no mark on the paper, that is to say, they create a blank between the words. The spaces are of four sorts, *hair, thin, middle,* and *thick* spaces. Besides these there are *quadrats,* or larger spaces, to fill out the breaks in sentences; these are *n* and *m* quadrats, and two, three, and four *m* quadrats. The shank or body of the *m* quadrat, we may add, is a perfect square, and is, therefore, used in measuring, just as an inch is in a foot.

The different kinds of type are measured by one standard. This type is the sort called *pica.* On the preceding page (87) are specimens of the types used in printing books, together with their names and some particulars respecting them. Besides these, there are others which are used for placards. For instance, *paragon; double-pica; two-line pica; two-line English; two-line great primer;* and *canon,* which is four times as large as pica. The types larger than canon have no distinct names, but are known as *five, six, seven, twenty,* or *fifty-line pica,* according to their size; that is, they are as wide, or as printers say, as deep, as five, six, seven, &c. lines of pica. For instance, the letter (fig. 682) is "ten-line pica Egyptian," and is as deep as ten lines of pica put together. Above 12-line pica, the letters are usually cut in wood—not cast in metal.

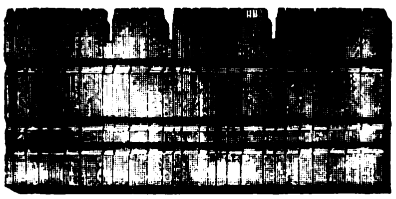
We have already given the broad outline of the art of type-founding as invented by Schœffer. It does not differ in principle from modern practice. There is, of course, a separate mould or matrix for each separate letter of the alphabet, and no less than 320 punches, and, of course, the same number of matrices are necessary, for the different varieties of letters, capitals, and small capitals, Roman and Italic, which form a complete fount of type. Fig. 653 is the form of a letter, which of course represents the shape of the interior of the mould. The mould is enclosed in two flat pieces of wood, and the metal is poured into it through a small funnel-shaped top. The type-metal is a mixture of lead, antimony, and tin, the proportions of which vary slightly with different type-founders; some add a minute portion of copper. The caster, after he has poured in the metal, jerks the mould upwards, by which the air is expelled, and the metal is forced into every part of it, so as to form the letters perfectly. Such letters as f and j, of small sizes, are now generally cast by the aid of a force-pump attached to the melting-pot, an improvement that saves the caster much time and trouble. The metal sets, or becomes solid, as soon as it has entered the mould. The process of casting, though apparently very primitive and clumsy, is performed with considerable expedition. A good workman will close the mould, cast the letter, open the mould, and remove the letter, in the eighth part of a minute; that is, he will cast 500 letters in an hour. The type made by hand is considered the best; but type is now made by machinery at the rate of thousands per hour. Each type as it is cast contains a piece of superfluous metal, which is broken off by a boy; the sides of every letter are then rubbed on a slab of gritty stone, for the purpose of removing knobs or globules; the letters are next set up in lines in a shallow frame, with the faces uppermost and the nicks outwards, when a man, called the *dresser,* polishes the types on each edge, and turning them with the face

653. SINGLE LETTER.

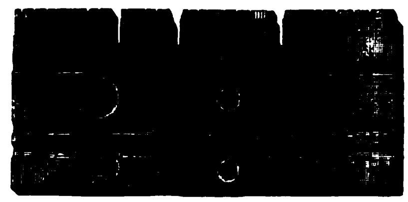


654. UPPER CASE.

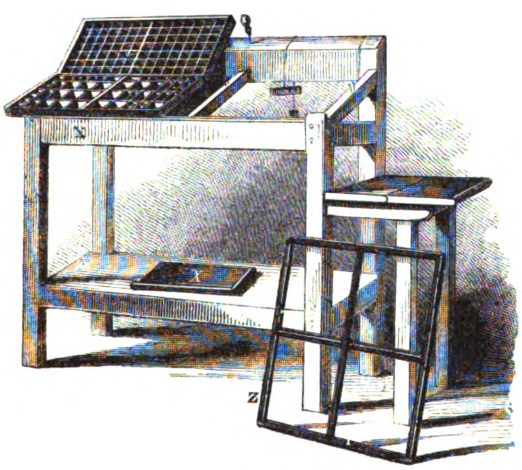
655. BODKIN.



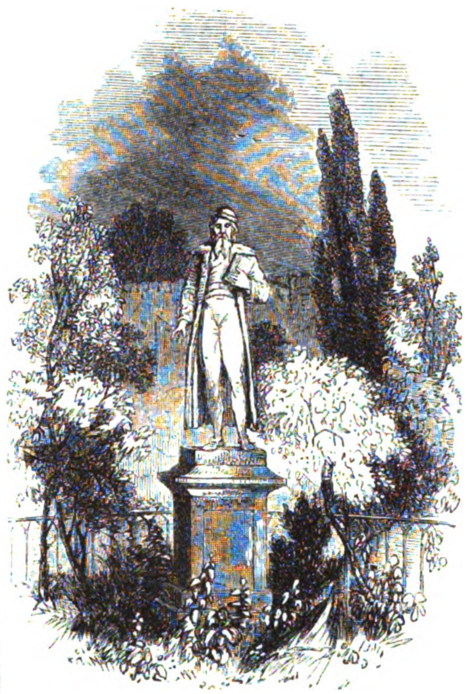
656. LINE OF TYPE, CORRECT.



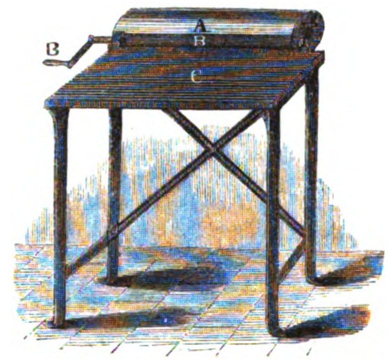
657. LINE OF TYPE WITH WRONG SORTS.



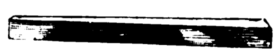
658. FRAME AND CASES.



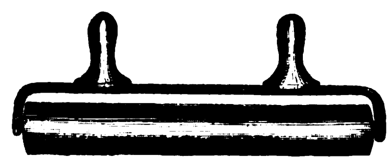
659. STATUE OF GUTENBERG.



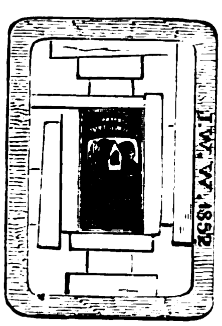
660. INKING TABLE.



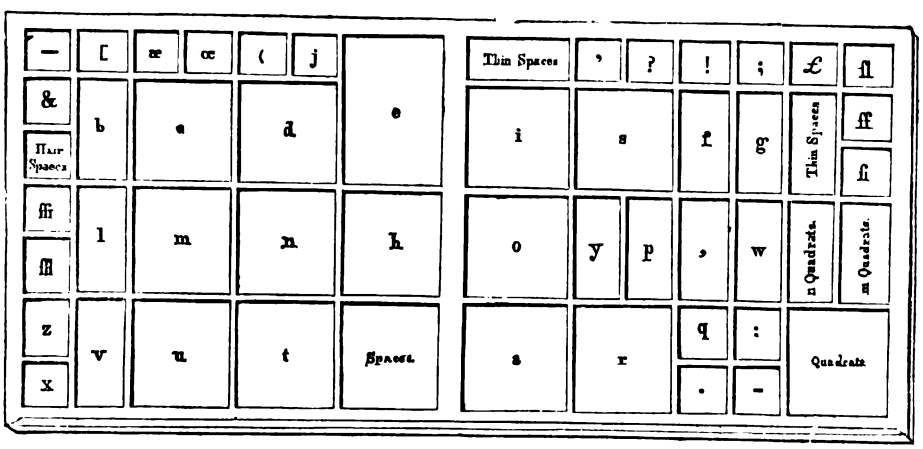
662 SIDE-STICK.



661. INKING ROLLER.

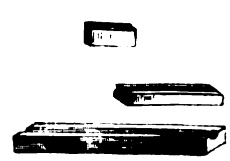


663. CHASE.



664. LOWER CASE.

665. REGLET.



666. FURNITURE.

N

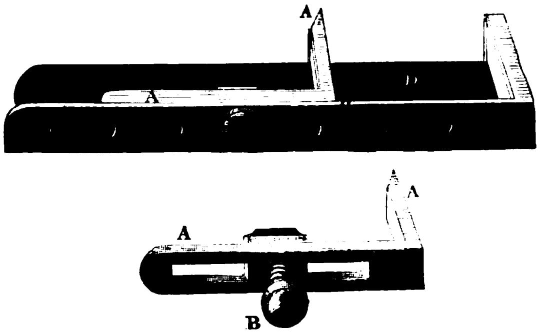
downwards, planes the bottom, and forms the groove which brings the types to the required height and allows them to stand steadily. The letters are next carefully inspected with a lens, and the fount being *proportioned*, that is, the proper proportion of each letter with spaces, quadrats, &c. being counted out, each letter &c. is tied up in lines for the printer. A complete fount of pica weighs 800 lbs.

The type is arranged at the printing office in cases, of which there are two, the *upper* and the *lower* case (figs. 654, 664). The upper case is divided into equal spaces or *boxes*, the left-hand division containing capital letters, dotted letters, figures, fractions, and a few other particular sorts; the right-hand division containing small capitals, accented letters, and note references. In this case the letters and figures are arranged in their alphabetical and numerical order, from left to right. In the lower case the divisions are unequal, the largest boxes being given to those letters which are most in request. The letter e has the largest box; c, d, m, n, h, u, t, i, s, o, a, r, have each boxes twice the size of those containing b, l, v, f, g, y, p, w, and four times the size of x, z, j, q, or the crotchets [ ], points and full points, double and treble letters, &c. The letter k occupies a spare box in the left-hand division of the upper case. The logotypes ff, fl, fi, ffi, and ffl, are required on account of the kerned f, which cannot be placed close to another f, an i, or an l. The boxes of letters most in request are nearest at hand: there is a separate pair of cases for the italic letters. The cases are placed on a *frame* (fig. 658), in which the blank space is usually occupied with the pair containing the italic fount.

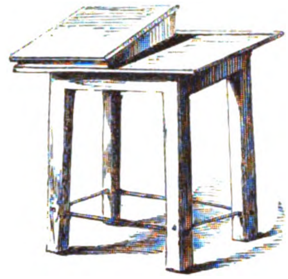
The person who sets up the type is called a *compositor*, who stands before the case, and placing his *copy*, that is, the author's manuscript, on a part of the upper case which is but little used, commences to pick up the letters required for the first words of the MS. In his left hand he holds a *composing stick* (fig. 667), in which the letters are arranged into words and lines: it is usually of iron from seven to ten inches long. The ledge AA is a moveable slide which can be adjusted by means of the screw B into any one of the holes, so as to make the space D wider or narrower, according to the width of the page which is to be printed. The compositor next selects a piece of brass rule, called a *setting* or *composing rule*, of the exact length of the line, and with a small ear or beak projecting at one end. This allows the letters to slip into their places without any obstruction from the screw-holes of the stick or the nicks in the type. The compositor then with the composing stick in his left hand, the fore-finger being bent under it, while the thumb is brought over the slider into the space D, first places the setting rule in the stick, and looking at his copy so as to carry a line or two in his memory, he takes a capital letter from the upper case and places it in the right angle of the composing stick; he selects the remaining letters of the first word from the lower case, and at the end of the word inserts a space. The compositor must make the words and spaces exactly fill the line by using thicker or thinner spaces as occasion requires. If at the end of a line the word cannot be divided, he drives it into the second line by wide spacing, or includes it in the first by narrow spacing. When he has completed the first line, he glances his eye over it to see that it is correct, and runs his left thumb along the front of the letters to feel if they are of the same fount. In this he is assisted by the nicks cut in the body of the type, and as each fount has its own system of nicks or notches, he can tell by feeling whether any of the letters are turned the wrong way, or are of the wrong fount, for in either case the lines of the grooves would be interrupted. Suppose, for example, the letter is what is called a three-nick letter, the appearance of a line will be that shown in fig. 656. But if either or both of the mistakes above referred to occur, the line will present some such appearance as in fig. 657. Having arrived at the end of the first line, the compositor takes out the setting rule and puts it in front of the line, which he forces back, and proceeds to compose the second line. In this way the setting rule serves as the basis for each new line. If the matter is to be *leaded*, that is, if the lines are to be farther apart than the type will allow, a flat ribbon of metal called a *lead*, of the exact width of the page, but from $\frac{1}{4}$th to $\frac{1}{8}$th the width of the type, and of the same height as the spaces, is inserted after each line is completed and before the rule is removed. Composing is not slow work, as might be supposed, for a good compositor will set 12,000 pica letters in a day. The composing stick generally holds about ten lines of pica, and as soon as it is full, the compositor lifts them out into a *galley*, shown at X, fig. 658: it is simply a thin piece of board with a ledge at one side, and at one end. When enough matter has been composed to make a sheet, the compositor proceeds to *impose* a *form*. *Imposing* is the arranging of the pages in such a manner that when the sheet of paper on which they are printed is folded, they shall follow, and read on in regular order. For this purpose the type is arranged in pages of equal length, with the same number of lines in each page, and being tied round with twine to prevent the letters from falling out, they are placed on the *imposing stone*. This is a slab of marble or of iron let into a frame. A sheet of folio which contains four pages would be laid, two pages on each side, as shown in the figure at page 87.

In arranging the pages, a line of quadrats is added at the bottom of each page, and at the top the *folio* of the page and the *running head*, which gives the title of the book, or of the chapter, or, still better, of the page. At the bottom of the first page the compositor places the *signature* or letter of the alphabet, which serves as a guide in *gathering*, *folding*, and *binding* the sheets. The pages being properly placed, he takes an iron frame, called a *chase* (a *quarto chase*, or one for four pages, is shown at Z, fig. 658), which is divided by cross-bars into compartments, places it down among the pages, and arranges between them a number of pieces of wood or metal called *furniture* (fig. 666). Within the chase, next to the pages, he places other pieces called *side and foot-sticks*, which are wider at one end than at the other, and between these and the chase he drives in small wedges or *quoins*. With a mallet and a *shooting-stick* (fig. 672), he drives the quoins in, and these acting with the force of the wedge, lock up the separate pieces of type so securely, that the chase may be lifted off the stone, without any danger of the letters falling out. The chase of type is called a *form*, and there are two forms, the outer and the inner form, for every sheet. (See the figures at page 87.)

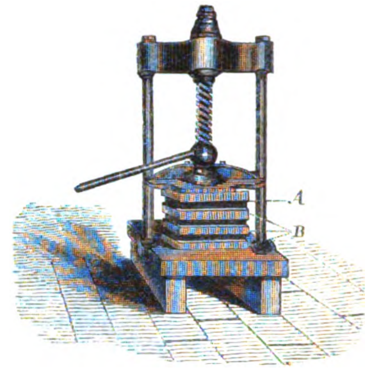
When the forms are removed from the stone, they are taken to a hand press, and a *proof* or impression of the sheet is *pulled*. This proof is placed in the hands of the first *reader*, or *corrector of the press*, who folds the sheet, examines the signatures, the folios, and the running heads, sees that the pages have been properly imposed, the chapters correctly numbered, the underlined words set up in italics, and the work done properly. A *reading boy* then reads the copy aloud in a rapid manner, and the reader corrects the mistakes of the compositor by drawing his pen through the letter or letters, and writing the correction in the margin. Then writing on the author's copy in the proper place the commencement, signature and folio of the succeeding sheet, he returns the sheet to the compositor, who proceeds to make the required corrections, for which purpose the form is placed on the stone, the type loosed or unlocked, and then, taking out by means of a *bodkin* (fig. 655) the wrong letter or letters, he inserts the correct ones. Should the compositor have omitted a sentence, he may have to do a great deal of his work over again, for he may have to *over-run* a large number of lines or even of pages, before he can get in the proper insertion. The errors being corrected, a second proof is pulled, which with the original proof goes back to the first reader, who sees that his corrections have been attended to, and if he is satisfied, forwards a clean proof to the *second reader*, who submits it to a searching revision, and marks not only compositors' mistakes, but queries the author's meaning, when it is, as it often is, obscure. The technical corrections of the second proof having been made, a clean proof is pulled for the author; the queries are marked in, in ink, and the proof with the copy is sent to the author. Should the author be satisfied with it, he returns it marked "For Press;"



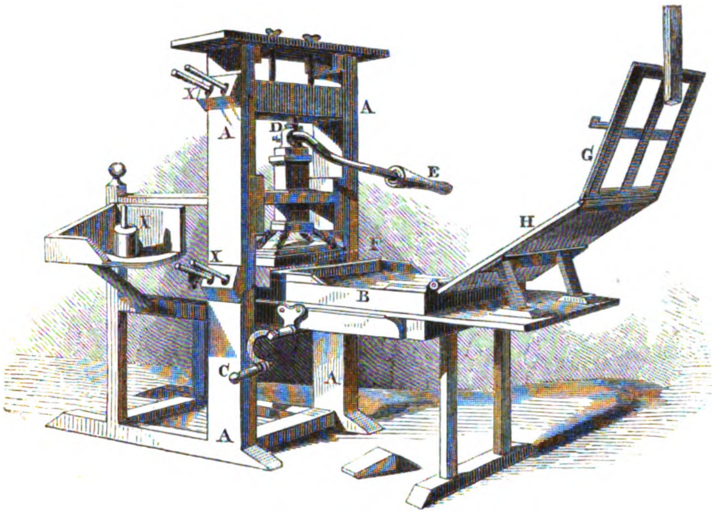
667. COMPOSING STICK.



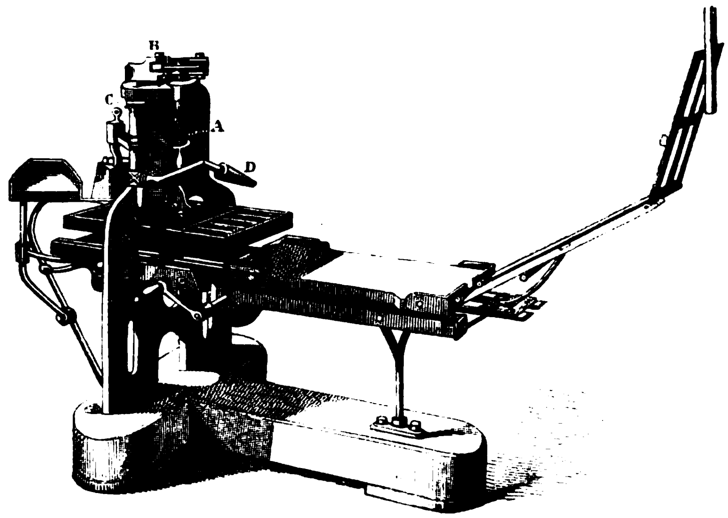
668. PRINTER'S HORSE AND BANK.



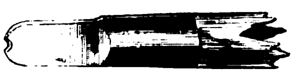
669. SCREW PRESS.



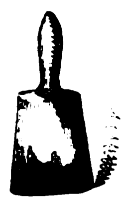
670. FIRST PRINTING PRESS.



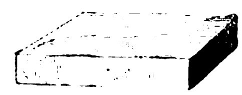
671. STANHOPE PRESS.



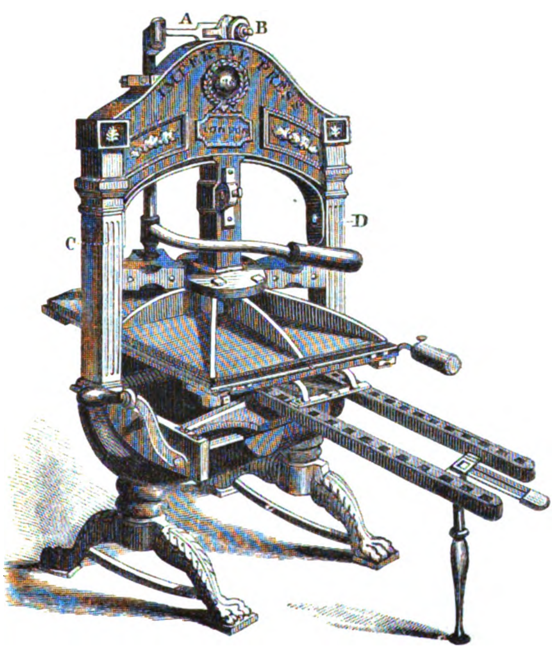
672. SHOOTING-STICK.



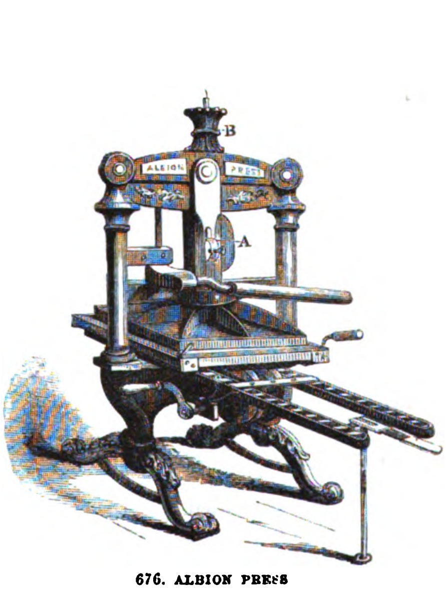
673. BRIER.



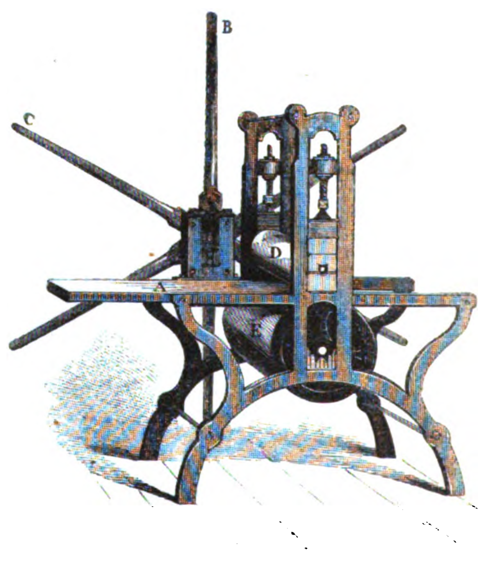
674. PLANER.



675. IMPERIAL PRESS.



676. ALBION PRESS



677. COPPER PLATE PRESS.

but should his corrections be numerous, he may require to see another proof, in which case he marks it "For Revise," and a second proof is sent to him, when his corrections have been made. When returned for press, it is once more read for the purpose of detecting minute technical errors, correcting the spacing, &c., and it is lastly sent to the press-room to be printed off. In the meantime the compositor is setting up another sheet of the work, and goes on until his type is exhausted; but before that happens, the first sheet will probably have been printed off, and the type returned to the compositor, who *distributes* it in his case by taking up a few words at a time between his finger and thumb and spelling out the letters into their proper boxes.

An old form of printing-press is represented in fig. 670, in which AA is the framework; B the board or table on which the types are placed to be printed; C the handle by which the table is rolled in to receive the pressure, the table standing on runners not unlike a railway. D is the screw, E the handle, and F the *platen*, by which the pressure is given. G is the *frisket*, an iron frame covered with paper, which in the engraving has been cut into four holes for the printing of four pages of type, and H is the *tympan*, consisting of a fine blanket laid between two skins of parchment, which are stretched on a square iron framework. The type to be printed is laid on the table, and inked with a soft roller, made principally of boiled glue and treacle. The printer lays a sheet of paper on the tympan, and turns down the frisket upon it. The object of the frisket is to keep the paper from falling off the tympan, and to prevent any part of it, except those parts which are to be printed on, from being inked, or, in other words, to keep that part of the sheet which is to form the margin, from getting soiled. After laying on the sheet, and turning the frisket down upon it, the printer doubles the tympan and frisket together, and turns them down upon the types, and then, turning the handle, he rolls the whole *carriage*, as it is called, under the platen. The bar is then pulled, the screw is thus turned round, and pressing down the platen the printing of the sheet is effected. The bar is then suffered to resume its former place, the screw thereby lifts the platen, the printer rolls out the carriage, unfolds the tympan and frisket, and removes the printed sheet.

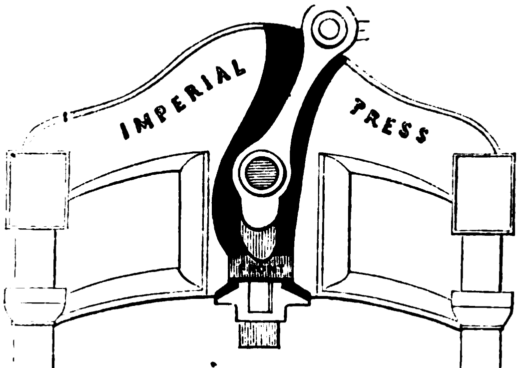
The first improvement in the printing press was made in 1620 by one Blaeu, or Blew, a Dutchman; and his press continued in use until the beginning of the present century, when it was superseded by the *Stanhope press*, (fig. 671), so called after Lord Stanhope, the inventor of it. His improvement consists in giving to the handle the power of a bent lever. The handle of the press previously used was fixed on the screw by which the pressure was given. Instead of this arrangement, Lord Stanhope succeeded in connecting the top of the screw by a short lever and a link, to the top of a spindle placed parallel to the screw. The handle of the press is attached to the end of this spindle; and when the workman first pulls the handle towards him, owing to the position the levers then occupy, the platen descends very fast, but on reaching the surface of the type, where, of course, the pressure is required, the levers have changed their position in such a manner that the platen moves more slowly but with much greater power. A is the screw; B the levers connecting the top of the screw with the spindle C, and D is the handle attached to the screw, which being turned, by pulling the handle, forces down the platen. The advantage arising from this arrangement of levers is, that platens twice as large as those previously used can be worked with far less strength. The platen of the old press was only half the size of the sheet of paper on which books are usually printed, as may be seen by comparing fig. 670 with fig. 671; and in consequence it was necessary to roll half the table under the platen, pull the handle, and print half the sheet, then roll the other half of the table under the platen, and pull the handle again before the whole of the sheet was printed. Lord Stanhope's press, however, admits of platens being made sufficiently large to cover the whole of the sheet at one time, while the bent lever handle enables the pull to be effected with greater ease. Furthermore, the increased power of the Stanhope press allows of the use of iron, instead of wood, in its construction, and this increases its efficiency, as wood yields to the power of the screw, while iron does not. Lord Stanhope's improvement was afterwards applied to wooden presses, the power of which was greatly increased by it.

The Stanhope press suggested a still greater improvement of the press. The screw which it retained was superseded entirely by a further use of the lever. Not only is the lever now employed to increase the power of the screw, but also to do the work of the screw. There are several kinds of presses, differing in their details, but using the lever to produce the impression instead of the screw. The screw is no longer used, but the lever is applied in many different ways. In the *Albion press*, for instance (fig. 676), two wedges or levers are placed within A, and when the press is idle they lie together something like the letter >; by pulling the bar-handle they are straightened like the knee on rising from a sitting position, and by their greater length force down the platen upon the type, and thus produce the impression. On the return of the bar-handle to its place of rest, the platen is lifted from the face of the type by means of a spiral spring fixed in the box B, and the two levers fall into the shape of a > again. The press, and those succeeding it, are shown with the tables rolled in under the platen.

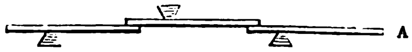
The *Imperial press* (fig. 675) is an improvement on the Albion. In this arrangement the bar-handle being pulled over, the levers A straighten the lever B, which fills a hole in the frame of the press, as in fig. 678. The straightening of this lever forces the platen down upon the face of the type. The platen is lifted again on the return of the bar-handle by two springs attached to the inside of the cheeks of the press, C D, but not shown in the engraving.

The *Columbian press* (fig. 680) is worked entirely with levers. The bar A being pulled, the rod B draws the elbow C inwards towards the cheek D, and thereby pulls down the head E. The head is not a fixed and immoveable part of the frame, as in other presses, but is a large lever, its fulcrum being the cheek I. The platen F is attached to the head by an iron bar H, and when the head is pulled down, the platen beneath this bar is forced down upon the face of the type. There is another lever, K, attached to the head bearing the eagle above it. The head in descending pulls downward the short arm of this lever, as the head rests on a fulcrum formed by the cheek D at *d*, and, in consequence, the opposite end, that is, M, bearing the eagle, is lifted upwards; this in falling draws the bar-handle back to its place of rest, lifts the platen, and raises the head.

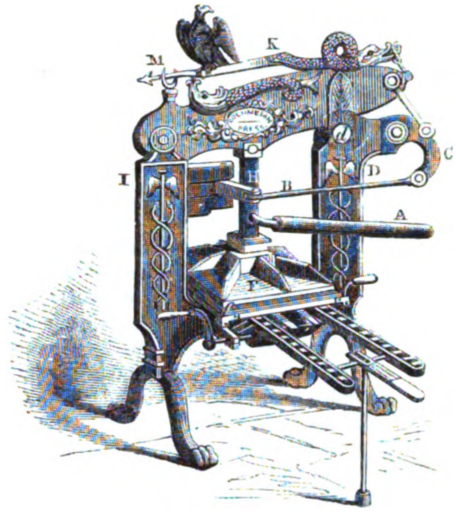
The principle and action of the Columbian press will not be thoroughly appreciated unless the principle and action of the compound lever are understood. For it is really nothing but a compound lever applied to printing; and, indeed, this may be said also of the Albion and Imperial presses, though they do not exhibit it so fully and clearly. It is known that an ounce weight placed on one end of a lever may be made to balance a pound placed at the other end of the lever, simply by lengthening the distance of the small weight, and shortening the distance of the large weight, from the *fulcrum* or point on which the lever rests. But the power of the lever may be enormously increased by using a number of levers in connexion with each other. For instance, let it be supposed that the three levers (fig. 679) are of the same length, the long arms of each 18 inches, and the short arms 1 inch. A pound weight placed at A would press the short arm against the long arm of the second lever with a force of 18 lbs.; this force of 18 lbs. acting on the long arm of the second lever would press down its short arm with a force of 324 lbs.; this force of 324 lbs. acting on the long arm of the third lever would force up the short arm with a force of 5832 lbs.! The rule is to multiply the weight by the length of the long arm of the lever, and the product is the force it exerts on the short arm. The levers by which the power of the Columbian press is obtained are much longer than in the above example, and consequently



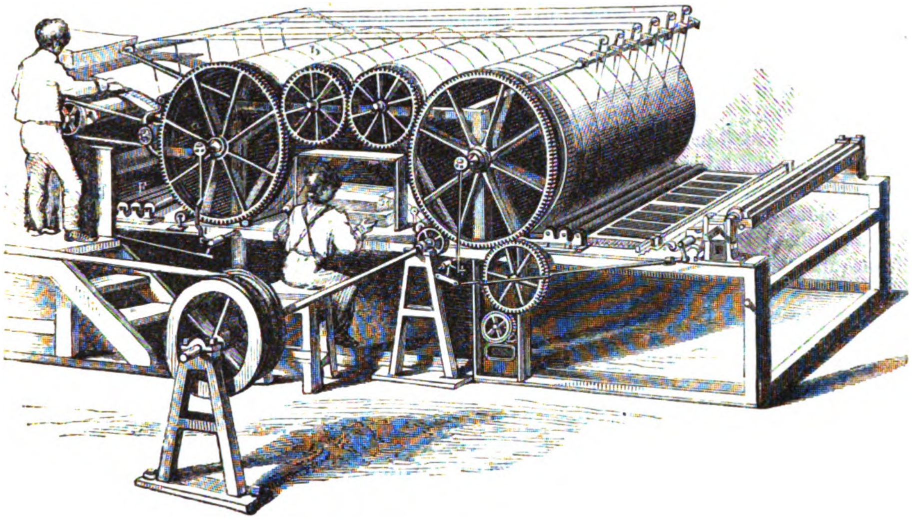
678. ARRANGEMENT OF LEVERS.



679. COMPOUND LEVER.

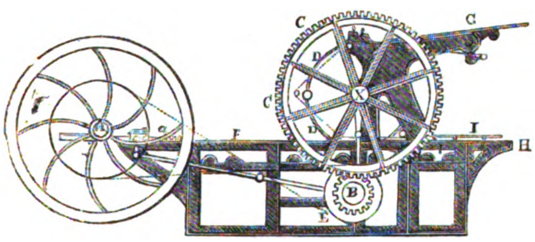


680. COLUMBIAN PRESS.

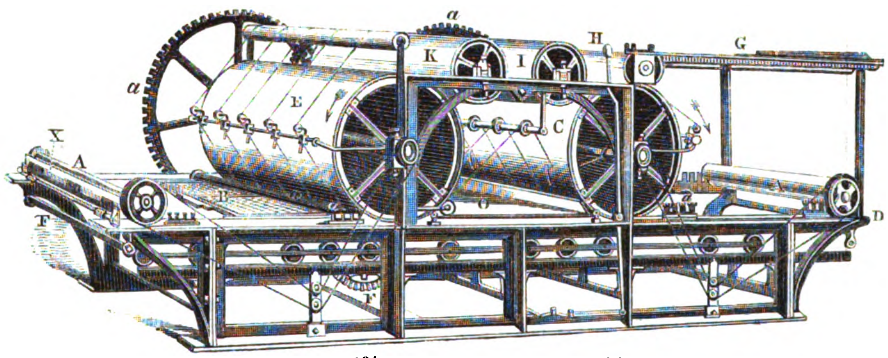


681. APPLEGATH AND COWPER'S MACHINE.

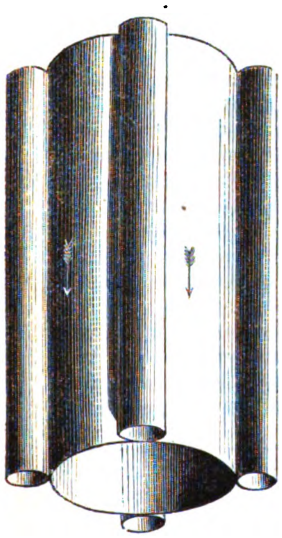
682. TEN-LINE PICA EGYPTIAN.



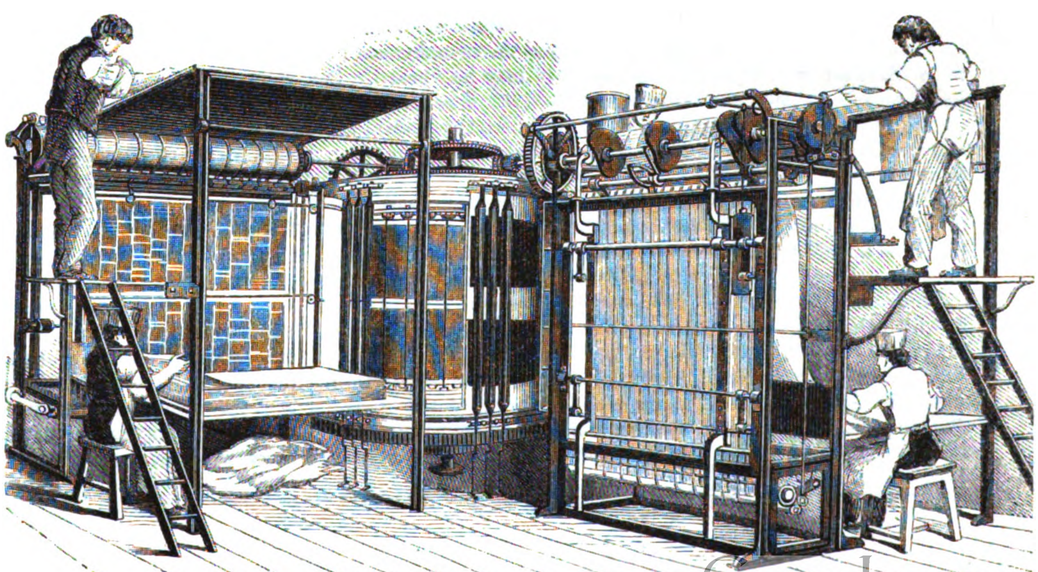
683. SINGLE CYLINDER MACHINE.



684. DOUBLE CYLINDER MACHINE.



685. PRINCIPLE OF VERTICAL CYLINDER MACHINE.



686. APPLEGATH'S VERTICAL CYLINDER MACHINE. (*Times* Printing Office.)

the force which they exert on the surface of the type is much greater. The length and number of the levers employed enable the pressman, by a gentle pull at the bar-handle, to give a severe pressure to the platen.

It will be understood that in all these printing presses the type has to be inked by hand after every impression. The old method of inking was by means of large leathern balls stuffed with horse-hair. These were dabbed down upon the type, and did the work in a very inconvenient manner: they were superseded by Professor Cowper's *inking-table* and *roller* (figs. 660 and 661), in which A is a large reservoir of ink, B a handle and cylinder, by turning which the ink is spread out, C the surface on which the inking-roller, having been supplied with ink by the cylinder B, distributes it. D is the inking-roller, which, being supplied equably with ink from the surface C, is rolled over the type. While one pressman is removing one sheet and laying on another, the second inks the form again by running the roller over it. Two men can in this way print 250 sheets an hour on one side only. The whole number of sheets having been thus worked off, they proceed to work the second form, or to print the sheet on the other side, which is called *perfecting*. The pages are kept back to back, or *in register*, by placing the points which hold the sheets on the tympan through the same holes in the centre as were used in printing the first side. When both sides are printed the sheets are hung up in the warehouse to dry; and as soon as the ink has hardened they are separated from each other and placed between sheets of thin glazed pasteboard, and subjected to the powerful pressure of a hydrostatic press, or of a *screw press* (fig. 669), in which A are the glazed boards, and B wooden boards to assist the screw. The object of this pressure is to remove the indentations formed by the type in the paper, and to give the paper a smooth, finished appearance.

In spite of all the improvements in the printing press it remained, and still remains, defective in two essential points. It is very slow, and great strength is required in working it. Only two men can work at it together, and these two cannot print more than 250 impressions an hour of what is now a small-sized sheet, that is, 2500 impressions a day, on one side of the paper only. No man is strong enough to give the pressure required in printing some of the large sheets, such as those of newspapers. The *printing machine* was therefore required to keep pace with the demand for reading, unless, indeed, it may be said that the supply and the demand stimulated each other. The machine excels in those points in which the press is defective. It prints swiftly, and it gives an enormous pressure. Instead of 250 small sheets an hour being the highest rate of printing, no less than 60 gigantic sheets are printed in a minute! This has been effected by substituting a hollow iron cylinder, or roller, for the platen or flat surface. The pressure, instead of being obtained by forcing a flat surface down upon the face of the type, is obtained by rolling a curved one over the face of the type. Again, instead of the motion being given by the strength of a man, it is now applied by a steam engine. The result is, that there is almost no limit to the speed of printing. The faster the machine can be fed with sheets to be printed, the faster it may be worked. It has been ascertained that a man can place 1250 sheets an hour on the feeder of the printing cylinder. If, then, the feeders are increased in number, the printing may in the same proportion be increased in rapidity.

The printing machine originated with Mr. Nicholson, who obtained a patent for it in 1790; but although he suggested the principle and sketched out the details, he did not actually produce a machine. A Saxon, named König, after many failures and disappointments, succeeded in constructing a cylinder machine, in which the types were inked by a self-acting contrivance, and the paper was printed by being passed under a roller. The machine was first set in operation at the manufactory in Whitecross-street, in April, 1811, and printed 3,000 sheets of the *Annual Register*, to the admiration of all persons who beheld it at work. It was, however, a very costly triumph. For in the seven years of experimenting, which it had required to bring König's ideas to bear, Mr. Bensley, the printer, spent no less a sum than 16,000*l*.

At this period *The Times* newspaper was in existence, though it had not then become what it is now, the first journal in the world. The publication of *The Times* had been commenced on the 1st of January, 1788, and it was a continuation of the *Daily Universal Register*, the first number of which had been issued exactly three years previously. Both these journals were "printed logographically," as it was styled, that is to say, the types did not consist of single letters; but syllables, whole words, and even phrases were cast in a piece. Mr. Walter, the proprietor of the papers, had taken out a patent for this kind of printing, in the idea that it would effect a saving both of time and labour, and consequently of expense. Out of the 90,000 words which the English language contains, he had ascertained that only 5,000 were in general use, and furthermore, that a great many of these had the same root, or, to use more familiar words, were the same in body, though differing in the head and tail. Take the word USE for an example. Use becomes *dis*use, *mis*use, use*ful*, use*less*, use*fulness*, and use*lessness*. It was found, however, that logographic printing, instead of saving, wasted time and labour. Time was, indeed, saved in having words in a piece, instead of composing them in separate letters; in being able, for instance, to take up "and the," or any other phrase at once, instead of by six motions of the hand; but then much more time was lost in running to and fro, to reach the place in which the words were kept. The ordinary pair of letter cases contains 151 boxes, which hold all the different letters used in printing, separated from each other, the a's being by themselves, the b's by themselves, and so on throughout the alphabet; and the compositor, without moving from the spot on which he stands, can reach every box with ease. But the cases in which the types of logographical printing were placed contained some hundreds of boxes; the cases themselves were four in number instead of two, and they were so large that the compositor had to walk backwards and forwards to get the sorts he wanted. Mr. Walter ultimately abandoned the system as impracticable. When, however, in 1788, the paper changed its name to *The Times*, and in the hands of Mr. Walter's son was managed with so much talent that the demand for it increased, that demand could not be supplied by the common press. The pressmen took advantage of the large sale of the paper to claim exorbitant wages. At this time the experiments by König and others as to the possibility of constructing a printing machine were going on; and Mr. Walter, in 1804, seriously set to work to try and supply the place of his troublesome hand-labourers by machine labour. He was long unsuccessful: it took ten years of anxiety, inventive skill, and a large expenditure of money, before anything like success was obtained. At length, however, on the night of the 19th of November, 1814, *The Times* was printed by the machine, as was announced in that paper next day, and it was thought a great triumph to be able to print 1,100 sheets in an hour. This machine printed only one side of the paper at a time; another was soon constructed which printed both sides before the sheet left the machine. This is what is called the *perfecting machine*. But these machines were complicated, and liable to get out of order. The principle having been put in practice, the engineers set about simplifying the invention. In this they triumphed over all difficulties. The original machine contained no less than 100 wheels; the number was reduced to 10. Mr. Edward Cowper, afterwards Professor of Manufacturing Art at King's College, London, for instance, on seeing *The Times* machine at work, suggested a slight alteration, by which wheels which had cost 1,500*l*. during the experiments were at once swept away. Gradually, printing machines were brought to a high state of perfection. They exhibit many different forms, but the same principle, that of the printing cylinder, pervades almost the whole of them. Their cost has been greatly reduced, their working rendered sure and safe, by simplifying the details, and their speed has been greatly increased. They are almost universally used for printing news-

papers, and very generally for printing books. Newspapers are printed better by machine than they could be by the ordinary press; but the machine is not so well calculated for *fine* printing, so that the most beautiful books are printed by the common press; but very good work is done by the *platen* machine.

The printing machines in general use may be divided into two classes, viz.:—*Single-cylinder machines*, which print one side of the sheet; and *double-cylinder machines*, which print both sides of the sheet before it leaves the machine. A double-cylinder machine may be compared to a couple of single-cylinder machines thrown into one. Fig. 683 represents the principle of a single-cylinder machine; but it must first be stated how the different parts of the machine are set in motion at the same time, and at the same speed, though some of them move in different directions, and even change their directions. If the machine is to be worked by men, a handle is inserted in the axis of the large wheel A; if it is to be worked by steam, then the wheel is replaced by another, connected by a band, as shown in the same figure, with the shaft of a steam-engine. The wheel A being turned round, the cord, shown by the dotted lines, turns the cogged wheel B; this wheel works in the cogs of a larger wheel C, and C turns the printing cylinder D behind, the two latter working on the same axis X. The little cogged wheel also turns a universal wheel, the place of which is indicated by the shading E, a part of the machinery on which it works, and the universal wheel sets in motion the table of the machine on which the form of type is placed. This table moves backward and forward within the framework F, F, on the little wheels beneath it. The printing is a very simple process. The sheets to be printed are placed on the board G; a man standing on a platform, as shown in fig. 681, moves sheet after sheet down to the top of the printing cylinder D, when it is caught by a cleverly contrived apparatus acting like the human hand, and is drawn within the tapes which go round the cylinder, as shown by the dotted line. When the printing cylinder begins to turn, the table also starts from the end at which the large wheel A is placed; the form inks itself by passing under the rollers indicated by *a*, and then slides towards the printing cylinder D: the form reaches the printing cylinder exactly when the latter has brought the edge of the sheet to the same point; and the sheet is printed by being pressed between the surface of the cylinder and the type, as they move towards the end of the machine H. The tapes, which have kept the sheet close to the surface of the printing cylinder, it will be seen, are not continued round the cylinder, but end under it. Thus the printed sheet is not carried upwards as the cylinder moves upwards, but is thrown off on the board I, and the form passes under the board. While that part of the cylinder on which the grippers are placed is rising to roll round another sheet, the table has shot back to the opposite end of the machine, the form obtains another supply of ink, and shoots back again, reaching the printing cylinder the very instant that it has brought down another sheet to be printed, as already described. This ingenious motion, forward and backward, is caused by the working of the universal wheel under the table.

Fig. 684 is a representation of a double-cylinder machine. The moving-wheels are at the back instead of the front, as in the representation of the single-cylinder machine. A A are the inking-rollers, which supply the forms with ink; and there is a set at each end of the machine, outside the large printing cylinders. The type is inked by the rollers *a a*. B is the form of type for printing one side of the sheet: the second form, for printing the second side, cannot be shown, as when one form is drawn out in the position of B, the other is drawn under the cylinder C. The forms glide backward and forward, B under cylinder E, and the other form under cylinder C, on a table similar to that of the common press, the table being set in motion by a wheel F. The moving machinery is indicated by the cog-wheels *a a*. A man stands on a platform with the sheets to be printed lying on a board G; he moves sheet after sheet downwards, until its edge meets the roller H, the end of which is just seen, and the sheet is caught within a series of endless tapes, which are shown by dotted lines extending throughout the machine, but they are too complicated to be clearly explained in words. These tapes, in moving in common with the machinery, carry the sheet in the direction of the downward arrow round the first printing cylinder C, and by the time that the sheet is half round, the bed of the machine has moved sufficiently to place the type under the cylinder C, and the cylinder and type move together in the direction of O, so that the first side of the paper is printed as it passes between them. The paper is now carried by the tapes upwards, over the cylinder I, and passing under the cylinder K, is carried round the outside of the second printing cylinder E. By the time the paper is half round again the second set of types has arrived under the cylinder E, and thus the second side of the paper is printed as it passes along between them. The sheet being thus perfected, is thrown out at O, where a boy sits to receive it. The object of the cylinders I and K is simply to convey the sheet smoothly from one printing cylinder to another. But how, it may be asked, is the sheet turned while it is passing through the machine to allow of its being printed on both sides?—By making the printing cylinders turn in opposite directions, and thereby passing the sheet down the outsides of them. If the sheet passed down the inside of the second cylinder E, the printed side would be presented to the second form of type: but by passing it outside, the paper is really reversed, and the unprinted side is presented to the type. It is difficult to explain this in words; but any one may see it clearly by taking a piece of paper and passing it over two rollers which are moving in different directions, in a similar manner to the printing cylinders. The printing machine exhibits some other beautiful contrivances for the regulation of its working; but it would be impossible to represent them in an engraving, and they must be seen to be understood.

The speed of a single-cylinder machine is, on the average, about 1,000 sheets an hour, and of a double-cylinder machine about 750 sheets an hour printed on both sides. The speed, as we have said, is limited by the power of feeding the machine with paper, and few men can lay on more than 1,250 sheets an hour. But a far greater speed has been attained by increasing the number of cylinders. For instance, Messrs. Applegath and Cowper constructed for the proprietors of *The Times* a machine which may be considered four machines in one. It had four printing cylinders, four feeding places, and four places where the printed sheet was thrown out, and the speed attained was 4,000 impressions an hour.

But even this speed has been outstripped. The circulation of *The Times*, the name of which is inseparably connected with the progress of machine printing, had grown so large that it became necessary to print it quicker than ever. The proprietors had recourse to Mr. Applegath, an engineer, who had done more than any other person for the improvement of the printing machine; and he has constructed one the simplicity of which is admirable, while its speed is practically without limit. It is a cylinder machine (fig. 686), but instead of the cylinders being placed horizontally as in the machine already described (figs. 681, 684), they are placed vertically, that is, like a drum standing on one end. The type is also fixed on the surface of the central cylinder, which turns round continuously, instead of being placed on a bed or table, moving backward and forward under the printing cylinders. Before we proceed to give a particular description of this wonderful machine, we may perhaps be able to convey a rough idea of it by the diagram fig. 685.

These cylinders represent the cylinders of the machine. It must be borne in mind that they stand upright like so many columns, the opposite ends pointing towards the ground. The types to be printed are fastened on the surface of the central cylinder A, and the whole of the cylinders turn round in the same direction. The small cylinders are really the printing cylinders. A sheet is put in at each of the places marked by the

arrow, it is drawn in by the motion of the machine and pressed against the large drum, and thrown out on the other side printed. Of course, it is so arranged that the type on the great cylinder shall arrive opposite each small cylinder at the instant that it is fed with a sheet of paper.

What we have just written simply illustrates the principle of the new printing machine. We will now endeavour to convey an idea of its details, taking for our example the superb machine by which *The Times* newspaper is printed. A large central cylinder or drum is erected, capable of being turned round on its axis. Upon the sides of this drum are fixed the columns of type by which the newspaper is printed, running straight up and down. The drum is 200 inches in circumference and 66 inches in diameter, and, therefore, the curve formed by its surface is so easy that the types stand almost square on their feet. The great drum is surrounded with eight smaller drums or rollers, also placed with the axis vertical, that is, like so many columns standing upright. Each of these cylinders is connected with the great drum by toothed wheels in such a manner that their surfaces must move at exactly the same rate as the surface of the drum. They are, in other words, so connected, that they can only move together and at the same speed. The printing is effected in this way. The drum and cylinders are set in motion; and in moving, the types on the surface of the drum become inked, and the eight cylinders are supplied with paper. The drum in passing round presses the type successively against each of the eight cylinders, and thus in turning round once eight sheets are printed.

Let us now explain how the type is inked eight times whilst the drum is turning round once: and how the eight cylinders are supplied with paper. Beside each of the eight paper cylinders are placed a set of inking rollers; near these are placed two ductor rollers. These ductor rollers receive a coating of ink from reservoirs placed above them. An inking table is attached to the great drum, and as it passes, receives a coating of ink from each of these rollers. The inking table next meets the rollers which ink the type, and transfers the coating of ink to them. Next, the types pass along, and encountering the inking rollers, receive the ink in turn. Next, the types encounter the paper on the cylinders, and thus they are printed. In a single revolution of the great central drum, therefore, the inking table receives a supply twice successively from the ductor rollers, delivers over that supply eight times successively to the inking rollers, which in their turn deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper upon the eight cylinders.

It remains to be explained how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, upon which a stock of unprinted paper is placed. An attendant standing by the side of the desk pushes the paper, sheet by sheet, towards an apparatus known as the *fingers* of the drum. These fingers, seizing the sheet by the edge, draw it straight down in a line with the drum, just as we draw down a window blind, and when it has descended sufficiently, a self-acting frame moves it sideways instead of downwards, and it is carried between tapes towards the printing cylinder. As it passes round the printing cylinder the types have been moved round sufficiently to print it. The sheet is then carried back, still sideways, by the same tapes on the other side of the frame, until it arrives at another desk upon which it is received by another attendant. It may be stated here that one of the difficulties which Mr. Applegath had to encounter in the construction of this machine was so to regulate the self-acting parts that the impression of the type should always be made in the centre of the page, and so that the print on one side of the paper might come exactly back to back with the print on the other side. This is generally accomplished, though an occasional deviation will occur. The type fixed on the drum moves round at the rate of five feet per second, and the paper to be printed is moved in contact with it, of course, at exactly the same rate. Now, if by any error in the placing of a sheet of paper, or in its motion, it should arrive at the printing cylinder so little as $\frac{1}{60}$th part of a second too soon or too late, that is, before or after the type has arrived opposite the printing cylinder, each column will be printed $\frac{1}{60}$th part of five feet out of its place, that is to say, one inch. In that case the edge of the print on one side of the sheet would be an inch nearer to the edge of the paper than the print on the other side. Such an incident rarely happens, but when it does the sheet is spoiled. Still the waste from the slipping of the sheets is considerably greater in the horizontal machine, than in the present vertical machine.

The movement of the vertical machine is round and round again without interruption. *The Times* machine prints no less than eight sheets at every revolution. The moment that one sheet is drawn into the machine, space is left for another, which the attendant immediately supplies, and in this manner the machine receives from him two sheets in every five seconds. As the same thing takes place at each of the eight cylinders, 16 sheets are drawn into the machine and printed every five seconds. *The Times* machine prints between 10,000 and 11,000 sheets an hour with ease; but if the men who place the sheets are very expert, it will work off from 12,000 to 13,000 an hour. Indeed, the rapidity of the machine is limited only by the power of the men to feed it with paper. If still greater speed were required, it might be obtained without changing the principle of the machine. It would only be necessary to increase the size of the great central drum carrying the type, so that a larger number of printing cylinders might be placed round it. If, for instance, a machine with eight cylinders will print 10,000 sheets an hour, a machine with sixteen cylinders would print 20,000 an hour.

Since this machine has been at work so successfully, an American machine has excited attention as being still more productive. The chief variation in its principle is in making the printing cylinder horizontal instead of vertical, so that the paper is introduced in the same position or nearly so in which it is printed; whereas in Applegath's machine, the position of the paper has to be changed from the horizontal one in which it feeds the machine to the vertical one in which it is printed.

The benefit arising from machine printing is incalculable. The machine has relieved men of hard toil which was often hurtful to health. Sheets of a greatly increased size can now be printed. The cost of printing has been greatly reduced, and the employment of printers considerably increased. The result has been an extraordinary diffusion of all kinds of knowledge, and a great advance in the civilization of the world.

It is a remarkable fact that a portion of the impression of every day's *Times* is printed in *stereotype*. The type is set up as usual for the advertisements and supplement, when a cast of it is taken in a pulp in which paper largely enters. This produces a sharp, clear impression, which is placed in a mould exactly adapted to the curvature of the printing cylinder, and melted stereotype metal being poured into it, an exact counterpart of the type is produced in a solid plate, the whole operation being performed in about half an hour. The plate is then screwed on to the printing cylinder, and when it has done its work, it can be melted up for the next day's service. It is usual, however, to take two casts of the same plate in case one should crack or break during the rough working of the machine; and it is this rough working which causes the rapid wear of the type, and originally suggested the stereotyping of a portion at least of the forms.

The art of stereotyping is usually applied to books of a permanent character, for which there is a steady demand. Its advantages are chiefly two-fold: it saves the publisher from printing a very large impression, which would require considerable warehouse room, and this in London is not a small item of expense; and on the other hand, should the publisher prefer to print a small impression of a book, he can do so by stereotyping, and thus save the costly process of setting up, correcting, &c. the work, every time he wants copies. Stereotyping is now so easily and quickly accomplished, that it is becoming more and more adopted.

XXXIII.—THE BOOKBINDER.

Although the art of bookbinding is strictly a trade, inasmuch as its operations are almost entirely confined to the labour of the hand, assisted by appropriate tools, yet in the magnitude of its operations it rivals the dignity of a manufacture. Readers are now so greatly multiplied, and the price of books is so much lessened, that editions which a few years ago could be reckoned by single thousands are now counted by tens of thousands. The binder has had to contribute his share to the cheapening of books, and he has succeeded in doing so by a skilful division of labour, and bringing into one large building branches of the trade which before were scattered. The introduction of cloth bindings instead of leather has also greatly cheapened the binding of books, and as an example of the celerity of the binder's work, we may notice that while the earlier operations of folding, sewing, ploughing, &c. are going on in one part of the building, the cloth boarded covers, with their embossing, gilding, &c. are being prepared in another. Indeed, an edition of several thousand books sent in quires to the binder's on Monday morning may be delivered *bound* on Wednesday evening.

In printing a book the sheets of any particular signature, A, B, C, &c. are collected together to the full number of the impression, that, is, all the sheets marked A are together, the same with the sheets B, &c. Now the first step preparatory to binding is called *gathering*, that is, a man takes a single sheet from signature A, another sheet from signature B, a third from signature C, and so on until he has got a complete copy of the work in sheets. It is more usual, however. to begin the gathering with the last signature, that is, supposing the signatures to extend from A to Z, taking a sheet of Z, placing upon this a sheet of Y, and so on up to A. All these gatherings are folded into *quires*, and in this state are delivered by the printer to the binder.

The first operation at the binders is *folding*. This is done by females, with the assistance of a folding-stick or paper-knife, taking care that one page shall be exactly opposite to another in each sheet, and that the signatures follow properly. A good folder will fold 400 or 500 octavo sheets in an hour. The folded sheets are next put into a hydrostatic press, for pressing them into a compact form and improving the surface of the paper. The old plan (still adopted by small binders with books not recently printed) was to beat the sheets on a large smooth stone, with an iron bell-shaped *hammer* (fig. 701), weighing twelve or fourteen lbs. This plan was to a great extent superseded by passing the sheets between iron rollers, which did the work in one twentieth of the time required by the hammer. Care must be taken in all these methods, especially with new books, that the ink of one page does not *set off* and disfigure the opposite page, which it is very liable to do.

The next operations are to collate each book, to see that the signatures run properly; to insert engravings, if any, in their proper places, and to add the waste leaves at the beginning and end. The back and head are then knocked up square, and the book is enclosed between a couple of pressing boards, with the back projecting a little way. The workman then places the boards with the sheets between them, between the jaws of the *cutting-press* (fig. 700), and passes a tenon saw across the back so as to make a number of grooves for receiving the cords or *bands*, for holding the threads in the sewing, and also for securing the boards of the covers. There is also a groove at each end for what is called the *catch* or *kettle* stitch. The sheets are then passed to the *sewing-press* (fig 687), in which it will be seen that the top rail holds three *bands* or strings, and they are made tight by being twisted into brass *keys* (one of which is shown at fig. 698) which pass through a groove below the flat board or basis of the press. The sewing is done by females, and the commonest kind, called *up and down work*, consists in taking two sheets at a time and passing a thread through the grooves of each alternately. For example, she passes the needle through the top kettle-stitch of the lower sheet, then out above the first band, and then into the upper sheet below the first band, then out above the second band, then below this band into the lower sheet, then out through the kettle-stitch of the lower sheet, then lastly this lower sheet is secured to the previous sheet by passing the thread round its lower kettle-stitch. Two more sheets are now taken, and the same routine is gone through. In some kinds of fine binding, the sheets are sewed all along and only one at a time, the thread being passed round every band. To prevent injury to the book, tapes are sometimes used instead of strings, and no grooves are sawn for the bands, for the holes thus made gradually enlarge in size as the book is used, and the only holes made when tape bands are used are those of the needle.

The folding and sewing are done by females; the rest of the work by men. The sewing is secured by brushing glue over the back of each book and covering this with a shred of paper or coarse, thin canvas, the latter, for certain kinds of binding, projecting in flaps at the sides for the purpose of holding the boards. When the glue is dry, the book is placed between a couple of boards with the side and bottom edges projecting, and these are cut off with a large knife: the folds of the sheets are not cut through, only a portion of the projecting uneven edges. The back is next rounded by placing the book flat, drawing the back on one side, and gently tapping it with a *broad-faced hammer* (fig. 699); the book is turned over and tapped on the other side, the effect of which is to make the back convex. The book is then placed between a couple of boards in a *screw-press* (fig. 700), with the back projecting, and is hammered so as to cause a ridge to project over the board on each side for the reception of the boards or side covers. The books are now ready for placing in their cases, which being done, the outside fly-leaf is pasted to the inner surface of the boards, and the books are built up with wooden boards into a pile and placed in a *standing-press* (fig. 692), where they undergo compression for some hours. The solid substance of the cases consists of mill-board, which is supplied to the binder in large sheets, and cut by him to the required size. Supposing the cover to be of cloth, this is cut out and stamped by means of embossing and other presses with the various borders and devices required. The binder receives the cloth in rolls or pieces each 40 yards long and 36 inches wide. The cloth is cut to the proper size of the cover with an extra quantity for overlapping, and the inside of each piece being covered with glue, the two mill-boards are placed upon it, at the distance required by the thickness of the book. A strip of paper or canvass is placed along the inside between the two boards; and the projecting edges of the cloth are folded in, and the whole is well rubbed down. In this way two men will make 100 covers in an hour. When the covers are dry, they are embossed and gilt. Such ornaments as are produced by pressure are called *blind-blocking*, and when done by hand *blind-tooling*, while the gilt ornaments and lettering are called *gold-blocking* or *gold-tooling*. Both descriptions of ornament are applied by means of *blocking-presses*, in which a plate or block of brass, with the ornamental pattern for the back or sides cut upon it, is fixed in the upper bed of the press and kept hot by a row of gas jets burning in a cavity of the upper bed. The cloth cover being inserted in the lower bed, a man with a long lever swings round the screw, and brings the upper bed with great force upon the cover, so as to emboss the impression. The cases then go to the gilders, who cover the parts intended to be gilt with a thin layer of white of egg, called *glaire*, and then with leaf gold. The covers are now passed to a gold-blocking press, which resembles the embossing press just described, only less force is required; the cover being

introduced into a properly adjusted bed, the heated brass block is brought down by means of a lever on the cover, with a gentle and equable pressure, which fixes the letters or device. As the covers are removed, the superfluous gold is wiped off with a piece of thick rag.

This style of binding refers to books bound in cloth with trimmed edges. For leather bindings the edges are not trimmed, but are cut through with a *plough* (fig. 690), so that the book does not require cutting open before reading, as in the former case. The bookbinder's plough consists of two cheeks, connected by a wooden screw, and a couple of guides ; in one of the cheeks is fixed a *cutting-knife*, two forms of which are shown in fig. 691 ; on turning the screw the two cheeks will be brought nearer together, and the knife attached to one cheek advanced inwards. The book to be ploughed is placed between wooden boards in the *press* (fig. 700), with the edges projecting, and one of the cheeks of the plough being placed in the grove of the press, the point of the knife is brought up to the book, and moved backwards and forwards against it : at the same time a twist is given to the screw, whereby the knife is advanced. The centre man in the *workshop* (fig. 694), is thus engaged in ploughing. The white edges of the book in common binding are next *sprinkled*, by dipping a brush into a mixture of Venetian red or ochre in size and water and knocking the brush against a piece of wood, so as to cause a shower of minute drops of colour to fall upon the edges. The colour is fixed by passing an agate burnisher over them, which produces a high polish. In the better class of binding the edges may be gilt or marbled. The boards, however, are first added, and secured by passing the short pieces of the bands left by the sewer through holes made in the boards. The edges, being nicely cut and secured between a couple of boards in the press, are covered with glaire, next with gold leaf, and then burnished with an agate burnisher. The marbling of the edges, and the making of marbled paper, constitute a distinct trade. The processes of the marbler are exceedingly curious and beautiful. Standing before a wooden trough containing a solution of gum tragacanth, he sprinkles upon the surface a number of colours which form disks, or blend together into veins, in a curious and complicated manner, with no art whatever of the workman, but depending solely upon the affinities or want of affinity of the colours for each other. Indeed, the art exercised by the workman rather disturbs than improves the effects produced naturally. What is called the *curl pattern* is produced by placing the pointed handle of a brush in the midst of the natural arrangement of colours, and giving it a spiral motion, whereby the colours are dragged into a spiral form. The *comb pattern* is formed by passing the handle of the brush in parallel stripes through the colour, and then passing the teeth of a comb through the colour. But whatever arrangement be made on the surface of the bath, if a sheet of paper be placed upon it and lifted off carefully by raising it by its two end corners, it will carry off the whole of the colour, and when dry requires only to be burnished to form a sheet of marbled paper, such as we see in the lining of books. This lining is inserted by the binder, and the books with their white edges being sent to the marbler, he produces on his bath the same pattern as that of the lining paper, and dipping the edges into the bath, they take up the colour without disturbing the arrangement of its pattern, and this, when dry, only requires to be burnished to fix it permanently.

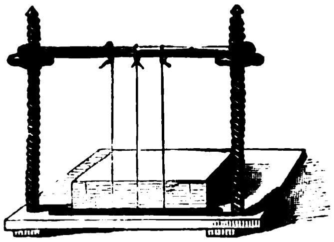
The *head-band*, which serves as a finish to the top and bottom of the book, is worked or stuck on, and bands, or raised projections at the back glued on, and then the leather, such as *calf*, *morocco*, or *Russia*, having been cut to the proper size, and the edges pared thin, is damped, covered with paste, then nicely put on, squared, and smoothed. When the leather is nicely fitted, the marbled or other lining papers are pasted down, and the book is put in the standing-press, preparatory to tooling. The *ornaments* are cut out in brass, as in fig. 695, and being heated at the *gas stove* (fig. 693), are pressed down upon the leather. A long line running along the sides of the book is usually cut, of the required pattern, on the edge of a disk of brass, and being mounted on a central axis and furnished with a handle, as in fig. 702, is run along the sides of the book. Gold tooling is produced by covering the parts with glaire, then with gold leaf, and pressing the hot tool upon the covered surface, the superfluous portion being wiped off with a rag Lettering is commonly performed by means of lettering tools, each letter being cut out in brass and mounted on a wooden handle, so that the man can spell out any title that may be required. Words in common use, such as ATLAS, VOL. &c. usually have separate tools, as in fig. 696. The binder is also furnished with polishing irons of various shapes and sizes (one of which is shown at fig. 697), which are heated and passed over the book for the finishing. Vellum binding, or that used for ledgers, account books, &c. forms a distinct branch of the trade.

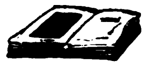
XXXIV.—THE ENGRAVER.

THE art of engraving affords pleasure and information, either independently of, or subservient to that of printing. By its means the works of the most celebrated painters, sculptors, and architects may be copied and multiplied, and even inserted in books to illustrate the subject the author has written on. In this respect engraving is of great value, for there are many things which words cannot so well describe as lines.

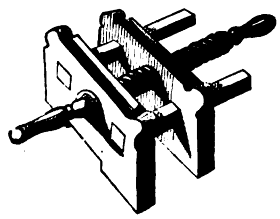
The engraver's art separates itself into three great divisions, namely, *chalcography*, or copper-plate engraving, from two Greek words, signifying *copper* and *I inscribe; zylography*, or wood-engraving, from the Greek for *wood* and *I inscribe;* and *lithography*, from the Greek for a *stone* and *I inscribe.* To these may be added *photographic* engraving, in which the sun does the work, and *electro-magnetic* engraving, in which an electro-motive machine is used to move the tool.

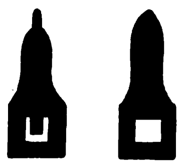
For the ordinary practice of copper-plate engraving, a plate of copper is made smooth and level, and is polished. On this plate the landscape or subject for engraving must be accurately drawn in outline. For this purpose the plate is heated, and a piece of white wax rubbed over it so as to cover it with a thin layer of that material. A careful tracing of the subject having been made in black-lead pencil is spread over the wax surface of the plate, with the lead lines in contact with it. Pressure is now applied in such a way as to transfer the lead lines from the paper to the wax. The tracing paper being removed the engraver goes over the subject with a fine steel point, so as just to penetrate the wax and touch the copper. The wax is then melted off; and the engraver, by means of a steel *graver* or *burin* (fig. 715), held in the hand at a small inclination to the surface of the copper, pushes the point forward so as to plough a line or furrow in the plate. The ridges or burs produced are removed by means of a steel *scraper*, but should the lines be cut too deep, a smooth tool, called a *burnisher* (fig. 719), is used to soften and rub them down. A woollen rubber is also used, with a little olive oil, to clear the face of the plate, and to polish off the bur. Writing engravers use a leather bag filled with sand as a cushion to support the plate during the work. A series of parallel lines or *tints* is usually put in by means of a ruling machine.

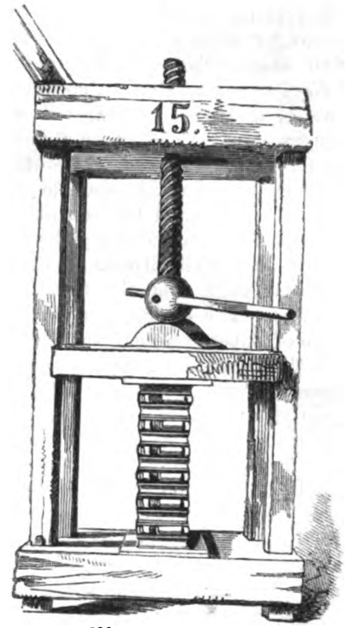

687. SEWING PRESS.


688. GOLD LEAF BOOK.

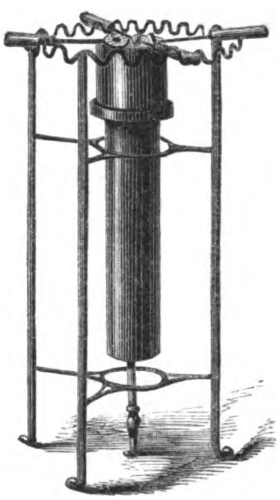

689. BLIND TOOLING BLOCK.

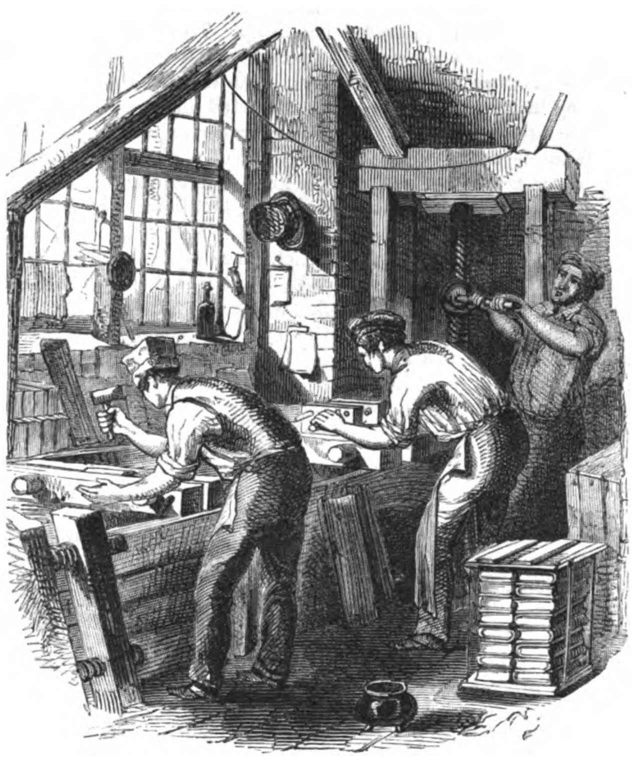

690. PLOUGH.

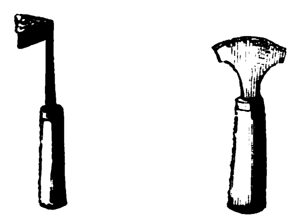

691. CUTTING BLADE OF PLOUGH.



692. STANDING PRESS.


693. GAS STOVE.

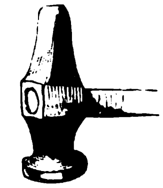

694. WORKSHOP.

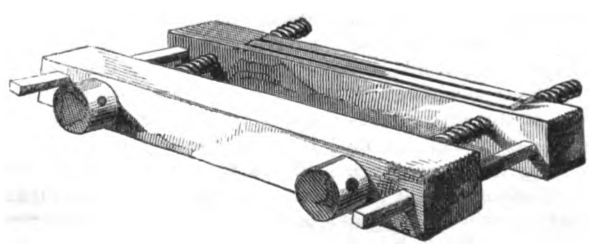

695. TOOLING INSTRUMENTS.

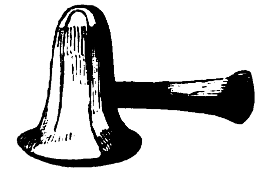

696. LETTERING TOOL.


697. POLISHING IRON.


698. BRASS KEY.


699. TOOLING HAMMER.


700. CUTTING PRESS.


701. HAMMER.

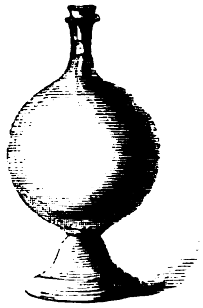
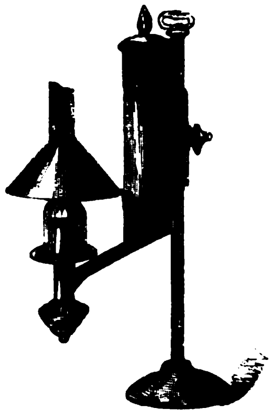

702. TOOLING INSTRUMENT.

Engraving is not usually so simple a process as the above, except for writing, the ornamentation of silver plate, &c. Most of the engraver's work is commenced and carried on by means of *etching*, which consists in corroding by means of aqua-fortis the lines of a drawing traced out with an etching-needle on the copper-plate, over which an etching ground of wax and pitch has been previously spread. The etching ground is made up into balls, tied up in silk, and the plate being heated, the silk is rubbed over it and the warmth causes the substance to ooze through. The ground is equalized by rubbing it with a *dauber*, or pad of silk stuffed with wool. The etching ground is then smoked by being held over the flames of two or three candles tied together. The design made in outline in black lead on a thin piece of paper is placed face downwards on the smoked surface, and thus passed through a roller press. The subject is then gone over with an etching needle, which scratches through the ground to the surface of the copper. A border of banking-wax is put round the edge of the plate, so as to form a trough for the aqua-fortis, which corrodes the part of the plate exposed by the needle, but has no action on the wax. When the fainter and more distant parts of the subject are sufficiently corroded, the acid is poured off, the plate washed with water, and these fainter parts are covered with *stopping ground*, which prevents the acid from acting any more on those parts. The acid is again poured on, and the action renewed on the bolder parts; and this *stopping-out* and *biting-in* can be repeated so as to produce numerous gradations of tint. The wax is removed by heating the plate, and the work is finished by hand. There are various effects produced by employing different methods. What is called the *dry point* is a very fine point used for cutting or scratching the more delicate lines of skies, &c. In engraving in *stipple* the subject is executed in dots instead of strokes. In *mezzo tinto* a dark ground is raised by means of a toothed tool, and the design being traced, the light parts are scraped off from the plate, according to the effect required. In *aqua tinta* the outline is sketched, and a kind of wash is laid on with aqua-fortis, so as to produce the effect of an Indian-ink drawing. Etching on steel is done in the same way as on copper; but there is this important advantage, that steel plates can be reproduced, while copper deteriorates by wear. One method of multiplying is to engrave the steel plate while the metal is soft, and then to harden by heating and suddenly cooling it. A cylinder of soft steel is then passed over the hardened plate, when it receives the impression in relief. The cylinder is next hardened, and then rolled upon a soft steel plate, by which means it transfers thereto a facsimile of the original engraving, capable, when hardened, of giving impressions as sharp as those of the original plate. The hardened cylinder can in this way produce a number of plates, which have only to be hardened to be fit for use. This method is now to a great extent superseded by the electrotype process, by which any number of copies of a copper or of a steel plate can be produced at small cost, and with less liability to injury of the original plate than the former process. There are many artistic advantages in engraving on copper, and it has lately been found that the wear and tear produced by printing can be prevented by covering the engraved plate with an extremely thin coating of iron or some other metal, deposited by means of the galvanic battery.

Wood engraving differs from copper and steel engraving in having the lines raised, while in the latter case they are sunk. Box wood, from its close, dense grain, is best adapted for wood engraving. It is cut into rounds of the shape of the trunk, and of thickness corresponding to the height of the type with which it is usually associated in printing; for one of the great advantages of wood engraving is that the engraved blocks can be mixed with the type, and printed with it in the same form. One surface of each *round* of box wood is nicely smoothed and polished, and covered with a thin wash of flake white and gum-water, and upon this the artist draws his subject with black lead pencils in reverse, so that when printed the left hand of the engraving shall appear right on the page. It is the business of the wood engraver to cut away those portions of the wood which the artist has not touched, so as to leave his lines in relief, and preserve those gradations in tint by which distances are expressed or various textures imitated. The wood engraver uses four kinds of tools, with various sizes and degrees of fineness of each kind. The first is the *graver* (fig. 715), which scarcely differs from that of the copper-plate engraver; eight or nine of these tools are required, beginning with the *outline tool*, and increasing in size and breadth. The second set of tools are known as *tinting tools* (fig. 714); they are thinner than the gravers, and ground to a more acute angle at the face, the object being that the shaving of wood may turn gently over towards the hand, and not coil over towards the point so as to hide the work. The other tools are *gouges* of different sizes (fig. 712), for scooping out the wood where depth is required, and flat tools (fig. 711), for cutting it away towards the edges. The method of holding the graver is attempted to be shown in fig. 716, but the drawing is badly done. It will be seen, however, that the force of the hand is checked by the thumb, which in large subjects rests upon the surface of the block, and in small subjects is rested against the side, the thumb being always ready to check the tool in case it should slip, for a block might be ruined if too much wood were cut away. To protect the drawing during the engraving, it is covered with paper, as in fig. 709, portions of which are torn away from time to time as the engraving proceeds. The block is supported on a *sand bag* (fig. 707), and this on a *box* (fig. 708). The engraver requires a good light, so that at night he works by the light of a *shaded lamp* (fig. 704); and to protect him from the heat of it, and at the same time to concentrate its rays upon his work, he allows the light to pass through a *globe of water* (fig. 703). The *engraver* is represented at work in fig. 713; the shade which he is represented as wearing over his eyes is objectionable, as it interferes with the circulation of the air. For very fine work a *magnifying glass* (fig. 710) is held in the eye, after the manner of the watchmaker. The man who is standing in fig. 713 is taking a proof of a finished engraving, or of one in progress, for which purpose he works a dabber on a stone with some printer's ink, dabs it upon the engraved surface, places upon this a sheet of soft India paper, and then burnishes it down with the tool (fig. 719). On raising the paper an impression will be found on it; several proofs are taken before the block is finished.

Lithography differs from copper-plate and wood engraving in this, that the lines are neither sunk nor left in relief, but are slightly raised above the surface of the stone. The stone used is a peculiar kind of calcareous rock, which imbibes water readily, while resinous or oily substances adhere to it strongly. A drawing made on the polished surface of the stone with a resinous or oily substance will adhere to it; and if a roller charged with printer's ink, which is of an oily nature, be passed over the stone, the ink will adhere to the drawing, and not to the other parts, which have been moistened with water after every impression.

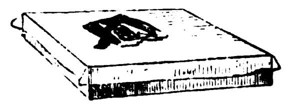
The lithographer's ink is made of tallow soap, white wax, lamp black, and a little tallow, boiled together. The drawing chalk is made in the same manner, with the addition of a little potash. When the drawing on the stone is dry, a weak solution of sulphuric acid is poured over it, which removes the potash from the chalk, and leaves an insoluble substance behind: at the same time it slightly lowers the surface of the stone not drawn upon, and prepares it for the free absorption of water. The stone is then washed with weak gum-water, and then with water. On applying a roller charged with printer's ink, the ink attaches itself to the oily or resinous drawing, but will evidently not adhere to the parts of the stone not drawn upon, from the simple circumstance that oil and water will not mix. The stone is then passed through the press, and an impression taken, and the washing with water and the inking are repeated after every impression. A drawing or writing made with lithographer's ink on

703. GLOBE. 704. LAMP. 705. PENKNIFE. 706. PENCIL.


707. SANDBAG.


708. BOX, SANDBAG, AND BLOCK.


709. BLOCK COVERED UP.

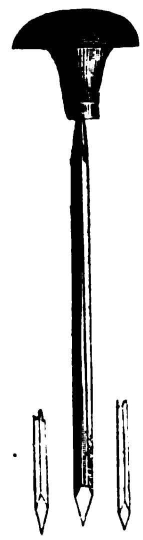

710. EYE-GLASS.


711. FLAT TOOLS.


712. SCOOPERS.

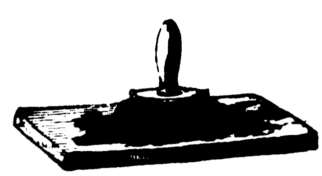

713. WORKSHOP.

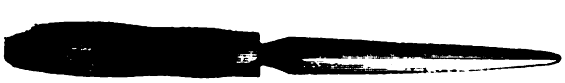

714. SHADE TOOLS.

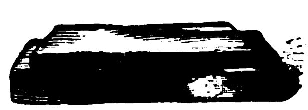

715. GRAVERS.

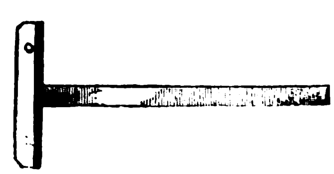

716. MODE OF ENGRAVING.


717. WAX.


718. DABBER ON SLAB.


719. BURNISHER.


720. OILSTONE.


721. T SQUARE.

sized paper can be transferred to the stone, and printed from as before.

The copper-plate printing press differs from the ordinary printing press: it is what is called a rolling press, and consists of two parts, the body and the carriage. The body is formed of two cheeks, with proper arrangements for holding the rollers, D E (fig. 677), and motion is given to the upper one by means of the long levers, C B, &c. In printing a copper or a steel plate the plate is raised to the temperature of about 180°, ink is dabbed on it, the surface is wiped with a piece of canvas, the ink is driven into the sunken lines, and cleaned off from the unengraved portions, by a skilful application of the hand, which is occasionally touched on a surface of whitening. Much skill is required in this *wiping* of the plate. The plate is now placed on the plank of the press, A, over the plate the damp paper which is to receive the impression, and over the paper two or three folds of flannel or blanket. The arms of the cross are then pulled, and the plate with its furniture is passed between the rollers, the equable pressure of which forces the moistened paper into the lines of the engraving, by which it absorbs the ink and retains the impression.

The lithographic press resembles the copper-plate press in several particulars, only the pressure is accompanied by a kind of scraping movement.

XXXV.—THE COOPER.

It is difficult to write concisely on the subject of any one trade, on account of the numerous branches into which it is nearly always split up. This is one of the useful results of competition; labour is sub-divided, and by keeping one man to the daily performance of the same limited task, he attains to an extraordinary amount of skill and rapidity in the performance of it, the effect of which not only insures excellence of workmanship, but cheapness of production.

Few trades are more sub-divided than that of the cooper. In the first place there is the *dry cooper*, whose business it is to make casks for holding goods that are not in a liquid state, such as sugar, flour, currants, &c. Secondly, the *wet* or *tight cooper* makes casks for all kinds of liquid goods, and this branch is again sub-divided into *large work* and *small work*, and these departments are so distinct that the men who practise one could scarcely earn a living at the other. In the third place there are *white coopers*, whose business it is to make tubs, pails, churns, &c.; fourthly, the *general cooper* professes to have a knowledge of all the branches of the trade, but as he seldom excels in any one, he would find it difficult to obtain employment in any yard or shop where only one branch was practised. Fifthly, there are *back makers*, who make the large underbacks, &c. of extensive breweries, but whose work differs in many respects from cooper's work.

As the various parts of a cask cannot be shaped by the rule and the square, as in carpenter's work, and yet must fit so tightly as to be water-tight, the cooper must have an accurate eye.

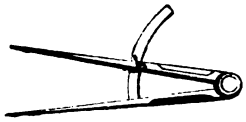
In what is called *small dry work*, the wood (generally oak or old ship timber) is sawn into lengths, and these into narrower pieces called *codlings;* these are *listed*, or reduced in size by an axe to make them narrower at the ends than in the middle, and they are then cleft by means of a cleaving-knife and a maul into staves or stave-pieces. The staves are *shaved* or *dressed*, so as to make them convex on one side and concave on the other; then *jointed*, so that when put together, the joints shall be tight. The cask heads are each made of one or two pieces. The staves are brought together by means of iron truss hoops, and are made to touch at their edges at the *boulge* or widest part, but are not yet closed in at the ends. In order to enable them to bend without cracking, the staves are heated, and the hoops by which they are to be held together are driven on. A groove is cut inside the two ends of the cask to receive the head and bottom. Wooden hoops of hazel, birch, willow, ash, or other tough wood, take the place of the truss hoops, and they are usually bent, notched, and fitted by separate workmen. The practice of *small wet work* resembles the small dry, only the parts are finished and adjusted with greater care, and iron hoops are often used instead of wooden ones.

The wood used for large dry work may be beech, ash, or oak. The staves are sawn to the required length, listed, dressed on the outside, jointed, and put together with the assistance of temporary hoops, much as in the case of small dry work, but for large wet or tight work, oak is preferred: Quebec and Virginia oak for spirit casks, and Danzic, Hamburgh, or English oak for beer casks. The wood is too tough to be split into stave-pieces, but is cut by a saw in various ways, as indicated by the terms *slab-staves*, *tongued-staves*, *straight-cut staves*, *doublet staves*. The joints must be smoothly and accurately brought together by the successive processes of *listing*, *jointing*, *backing*, *shaving*, *head-making*, *dowelling*, *firing*, *trussing*, *grooving*, *heading*, and *hooping*, and in most cases the cask must be an exact measure—as in a barrel of beer, it must hold thirty-six gallons—all of which requires good workmanship and an accurate eye. The middle of the cask is called the *boulge*, and the space between the middle and the end is called the *quarter*. The cask should form what is called a *perfect figure*, that is, it should form a perfect curve from end to end. A cask is called *high* or *low boulged* according to its amount of curvature from end to end. A cask which has more boulge at one part than another, is called by the workmen a *lord*, and if larger at one end than the other, a *church*, or steeple-ended cask.

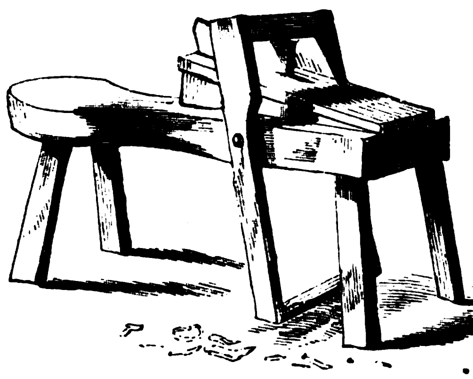
In white-work, such as tubs, pails, &c. which are usually larger at the top than at the bottom, oak or ash is generally used, and the work is smoothed on the inside as well as on the out, which is not the case with casks. Most of the work is done with a *shave*, of which there are several forms.

Back-making belongs to carpentering rather than to cooperage. The bottom is set up first, and the staves are fitted in and pegged to each other, without reference to any particular proportion, for some are wide at the top and narrow at the bottom, and *vice versâ;* but the back-maker makes everything tight by accurately adjusting the size and form of the finishing or filling-up pieces.

The tools used by the cooper are few and simple, the *axe* (fig. 741), for splitting out the staves and listing them; a pair of *compasses* (fig. 722), for measuring or *laying out* the timber after it has been cleft; the *horse* (fig. 724), on which the workman sits (fig. 731) for the purpose of dressing or shaving the staves to the right thickness, is of wood, the man with his feet works a frame, which nips the stave and holds it firmly while it is shaved with a *cramp* knife. In shaving the staves round on the outside and hollow on the inside, the cramp knife is made slightly round at one end and hollow at the other. In jointing or preparing the sides or edges of the staves so that they shall fit well, a long plane

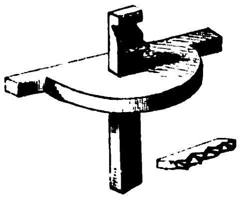


722. COMPASSES.

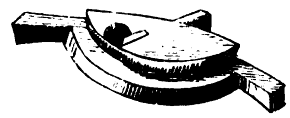


724 HORSE.

725. FLAGGING IRON.

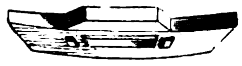


723 CROSE.

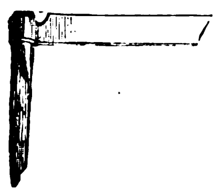


726. CHIVE.

729. ROUNDING IRON.

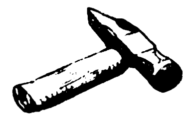


727. SPOKESHAVE.



730. CLEARING IRON.

731. WORKSHOP.

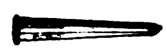


728. BEATING HAMMER.

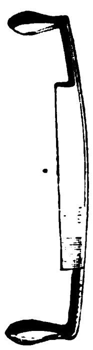
732. HAND SAW.

733. NARROW SAW.

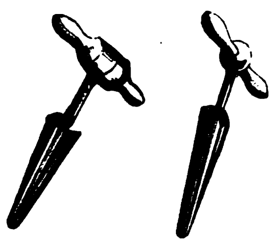
737. BICK IRON.



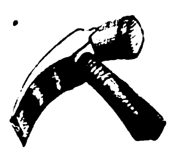
736. PUNCH.



734. DRAWING KNIFE.



735. BUNG BORERS.

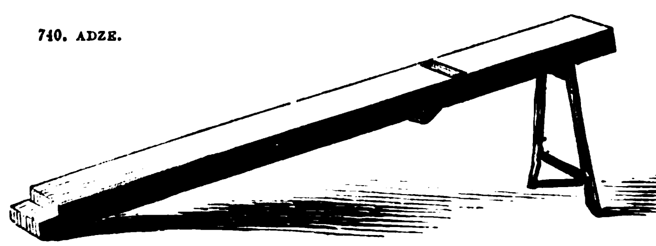


740. ADZE.

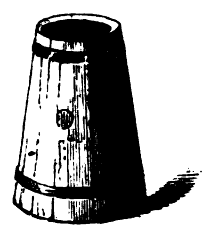
738. CENTRE BIT.

739. DRIVER.

741. AXE AND BLOCK.



742. JOINTER.



743. TUB.

or *jointer* (fig. 742) is used. It has the cutting part upwards, and for small staves the lower end of the jointer is fixed against a bench, and for larger staves against a block in the ground or floor; the upper end is supported by a pair of legs. The heads are prepared by the *head-jointer*, which is nearly, but not quite flat. The *stave-jointer* is more or less concave, but the head-jointer is slightly convex on the surface. For wet-work the pieces of wood for the head are secured together by means of pegs, and a piece of flag or rush is inserted between the joints, and when the head is put in, joints that are too open must be flagged, and if the head be in the slightest degree too small, it should have a flag all round the groove. In inserting a flag in a joint, the joint is opened wider by means of a lever called a *flagging iron* (fig. 725), the two prongs being used on different staves and a side-pressure being exerted on the arm. The necessary *quarter*, or curvature between the centre and the end, is given to the stave by shaving from the centre to each end. In setting up the cask and bringing the edges together by means of truss hoops, six hoops for a small cask make a truss; they are called *head-hoops*, *quarter-hoops*, and *boulge-hoops;* larger casks have two additional quarter-hoops, namely, a *raising-hoop* and an *over-runner*. The iron hoops are formed on the *beak-iron* (fig. 737), the holes being useful in forming the rivet. In firing a keg so as to be able to bend the staves, a small *cresset* or skeleton grate, made of iron hoops, is filled with chips or shavings, and lighted: the keg or cask is then placed over or round it, and when the sap is warmed, the staves will bend without cracking. The workman then tightens the hoops by blows with the *hammer* and *driver* (figs. 728, 739), and when all the hoops are driven on, the keg is said to be *close-trussed*, or gathered in. The staves being now all bent, and to set or fix them in this bent position, heat is again applied. It is then removed from the fire, the truss-hoops are driven hard, and the ends of the keg are pared quite smooth with the drawing-knife. Then by means of a *chive* (fig. 726) he will smooth the inner surface of the end, and prepare a place for the groove. This groove is formed by means of a *crose* (fig. 723), that for kegs and small casks being called a *saw-crose*, and used by working it backwards and forwards. The compasses are used for describing the circle for the head, and the wood is cut, first roughly with the axe, then with a hand-knife or the drawing-knife. In removing the truss-hoops preparatory to putting on the wooden hoops, the roughnesses of the wood, and the black stains left by the iron truss-hoops, are removed by the *spoke-shave* (fig. 727). In large casks the work is pared off with the *adze* (fig. 740), so as to make the sloping part of the chime of the cask. The adze is a most difficult tool to use, and equally difficult to grind or to give it the proper edge. In using the adze, the wrist should be kept as stiff as possible, and the motion be from the elbow joint.

The above particulars (for which we are mainly indebted to an admirable little treatise in Mr. Charles Knight's "Guide to Trade") will give a sufficient idea of the trade of the cooper.

XXXVI.—THE SOAP-BOILER.

THE manufacture of soap depends on certain chemical principles which have only of late years been properly understood, thus affording one out of many examples in which the useful arts preceded scientific discovery. The soap-boiler at the present day is seldom a chemist. He prepares his soap according to certain rules which have been found to succeed; but in taking account of them it is our duty to endeavour to understand them.

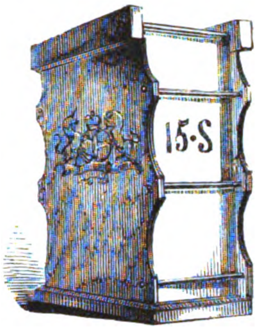
Soap is a compound of certain fatty substances with soda or potash. It depends for its cleansing action entirely upon the alkali, a portion of which, combining with the greasy matters intended to be removed by washing, renders them soluble in water. The caustic alkali would act more powerfully as a detergent if used alone; but then it would corrode many substances exposed to its action, and would destroy the colours of some goods. The *lye* obtained by filtering water through wood ashes is a solution of potash more or less caustic. By exposure to the air caustic potash and soda absorb carbonic acid gas, which converts them into mild carbonates.

Fats consist of two proximate fatty substances, namely, *oleine*, which is fluid at common temperatures, and *stearine*, which is solid; and fats vary in softness or solidity according to the proportions in which these two bodies exist. Stearine may also contain an analogous substance, *margarine*, in various proportions. The solid fat or tallow of the sheep contains chiefly stearine; lard and olive oil contain for the most part margarine; the solid fat of palm oil is called *palmitine;* that of cocoa-nut oil, *cocine.* Now all these substances are compounds of fatty acids with a sweet substance called *glycerine:* thus, the acid of oleine is *oleic acid*, which combined with the glycerine of the oleine forms *oleate of glycerine*. Stearine contains *stearic acid*, and forms with the glycerine of the stearine *stearate of glycerine*, and so on. Now when stearine, oleine, &c. are mixed with the alkalies, potash or soda, they are decomposed, and their acids quit the glycerine to unite with the alkalies, while the glycerine is thrown out. The hard soaps of commerce, when made with oils (except those of the palm and the cocoa-nut), are for the most part mixtures of oleate and margarate of soda, with little, if any, stearate: when made with animal fats they are mixtures of oleate, stearate, and margarate of soda. When lime is used an insoluble soap is formed, as may be seen when washing with hard water, soap forms in flakes without dissolving. In such cases the carbonate or sulphate of lime of the water unites with the fatty acids of the soap, forming an insoluble compound, while the carbonic or sulphuric acid of the lime combines with the alkali of the soap.

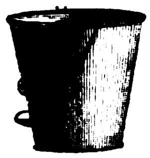
Soaps are divided into *hard* and *soft*. The former are made from fats and vegetable oils, with soda as a base; the latter from fish oil or vegetable drying oil, with potash as a base. Stearate of soda may be taken as the representative of hard soaps, and stearate of potash, which is a thick paste, of the soft. In this country, white soap is made of tallow and soda; one ton of soap takes from 10 cwt. to 14 cwt. of tallow, with a proportion of alkali which varies in different works. In Windsor soap the tallow is mixed with about 10 per cent. of inferior olive oil, and in white soap a portion of lard takes the place of an equal part of the tallow. Common rosin unites with alkalies; and when boiled with soda it forms a *pinate* of soda, which gives the distinctive character to yellow soap.

The alkali as received at the soap works is usually in the form of a carbonate; and it must be made caustic by getting rid of the carbonic acid, for which purpose it is mixed with recently slaked lime, which takes up the carbonic acid, and forms an insoluble carbonate of lime or chalk, and leaves the soda in solution in a caustic state.

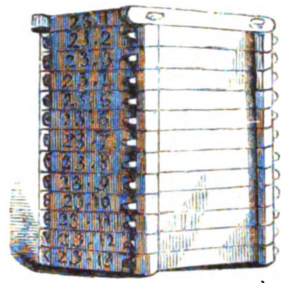
Soap is usually manufactured by one of two processes. The first is the *cold* or *small boiler process*, in which the temperature is kept below the boiling point of water, and the vessels in which it is conducted are comparatively small. The second and common method is the *large boiler process*, in which the boilers or *coppers*,



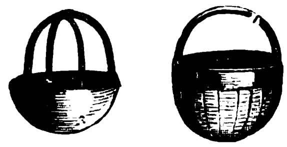
744. FRAME.



745. BUCKET.

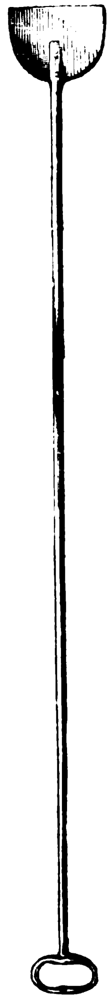


748. FRAME.



746. SWIMMERS.

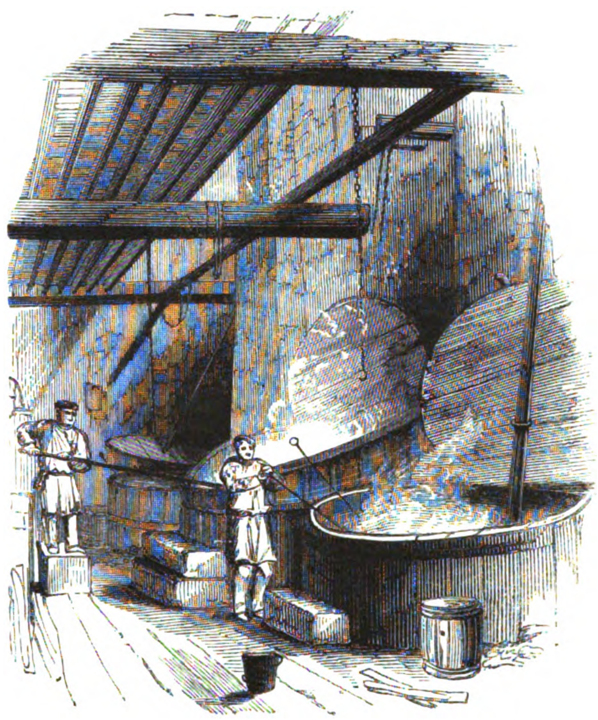
747. WIRE FOR CUTTING SOAP.



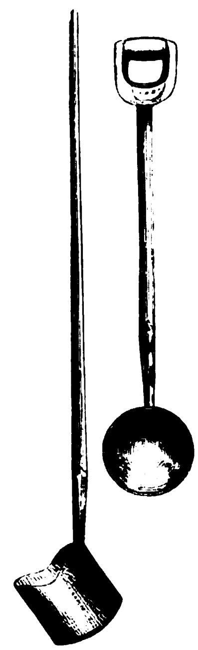
749. SCRAPER.

750. FORK.

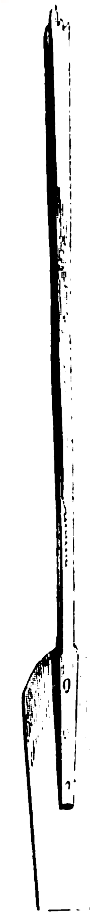
751. GAUGE.



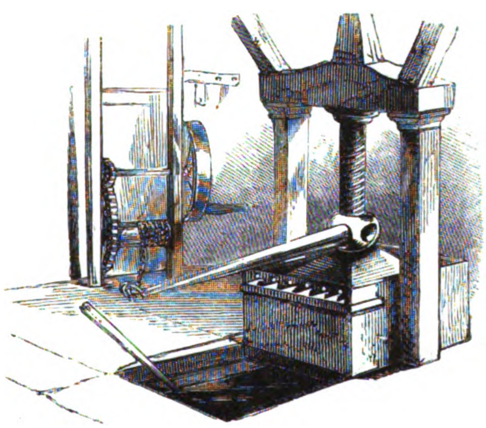
752. BOILING HOUSE.



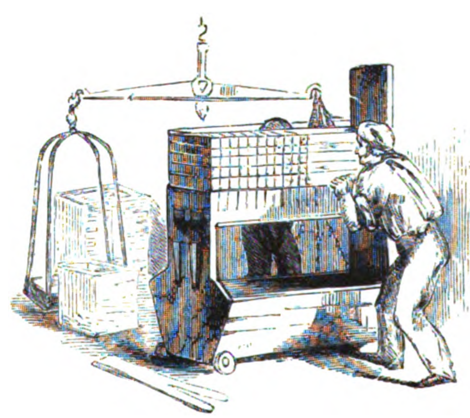
753. SCOOPS.



754. SCATER.



755. PRESS.



756. CUTTING SOAP INTO BARS.

as they are called, though made of cast iron (fig. 752), will each hold many tons. The latter process we will briefly describe. The whole of the oil or tallow is introduced at once into the copper, but the alkali is added in separate portions. First, a weak solution is pumped up, and heat is applied until the lye ceases to be caustic. A certain quantity of salt is also added, the solution of which occupies the bottom of the copper and prevents the tallow from burning; it also has another use, which will be noticed presently. When the tallow and the lye by stirring make a uniform emulsion, the copper is allowed to cool, and the spent lye, containing some of the glycerine of the fat and the common salt, are pumped up and left to run to waste. Now it must be understood that when a soluble soap is made by boiling a caustic solution of soda or of potash with stearine, the stearate of soda or soap remains suspended in the water of the solution, together with the glycerine. Now by the addition of a solution of common salt, in which soap is not soluble, but glycerine is so, the soap separates from the water and the glycerine, and floats on the surface. In this way the glycerine is got rid of by pumping it up from the bottom of the copper. The first boiling is called an *operation;* and three or four operations with leys gradually increasing in strength are required to produce saponification, or to "kill the grease," as the workmen call it. The tallow is known to be saponified when a small portion pressed between the finger and thumb cools into a hard cake and has acquired a slightly alkaline taste, whereas if any of the tallow remain unsaponified it will ooze out by pressure. In making common yellow soap the rosin is added towards the end, and forms one-third or one-fourth the weight of the tallow.

When the saponification is complete, the soap is a collection of innumerable distinct globules; and to make them coalesce, a weak lye is added and the boiling is kept up for some time, large shovels or *scates* (fig. 754) being dashed into the mass from time to time (see fig. 752). During this part of the process the black impurities of the materials, called *nigre*, are allowed to subside, and *white* or *curd soap* is the result; but for *mottled soap* the mixture is left very thick, so that the nigre cannot subside. When the fire is extinguished the lid of the copper is let down, and the whole is left down for one, two, or three days, according to the kind of soap, after which the semi-fluid mass is ladled out into rectangular *frames* or *sesses* (figs. 744, 748), each 45 inches long by 15 inches wide, and about 10 inches deep. They are numbered, and piled upon each other as in fig. 748, and bound by iron screw rods so as to form a kind of rectangular cistern 10 or 12 feet deep, so as to hold about two tons of soap. The soap cools and solidifies in the frames. The *frame* fig. 744 is of cast iron, and is used for yellow soap; fig. 748 for white or mottled. When the soap is sufficiently solidified the screw rods are removed, the frames lifted off, and the soap stands as a solid block. It is scored by the *gauge* (fig. 751), and cut by drawing a *wire* (fig. 747) through it, as shown in fig. 756. It is first cut into slabs, and the slabs into bars; these are piled away cross-wise to allow the air to circulate, and the soap is now ready for sale.

The nigre which remains in mottled soap is chiefly a sulphuret of iron, caused by the action on the boiler of a little sulphuret of sodium contained in the alkali. When the soap is ladled out of the boiler the nigre is equally diffused through the mass, but in draining it separates into veins, and gives the mottled appearance. *Marbled* soap is formed by sprinkling a small portion of lye strongly impregnated with sulphuret of iron upon the soap just after the last boiling. *Toilet soaps* do not differ from curd or white soaps except by the addition of various perfumes, colours, &c. The vermilion or ultramarine marbling is produced by partially mixing a little of those colours with the soap in a melted state. Cakes or tablets are formed in a mould in a lever press.

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